A mechanism for the strange metal phase in rare-earth intermetallic compounds

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A major mystery in strongly interacting quantum systems is the microscopic origin of the "strange metal" phenomenology, with unconventional metallic behavior that defies Landau's Fermi liquid framework for ordinary metals. This state is found across a wide range of quantum materials, notably in rare-earth intermetallic compounds at finite temperatures (T) near a magnetic quantum phase transition, and shows a quasilinear-in-temperature resistivity and a logarithmic-in-temperature specific heat coefficient. Recently, an even more enigmatic behavior pointing toward a stable strange metal ground state was observed in $CePd_{1-x}Ni_xAl$, a geometrically frustrated Kondo lattice compound. Here, we propose a mechanism for such phenomena driven by the interplay of the gapless fermionic short-ranged antiferromagnetic spin correlations (spinons) and critical bosonic charge (holons) fluctuations near a Kondo breakdown quantum phase transition [1]. Within a dynamical large-N approach to the Kondo–Heisenberg lattice model, the strange metal phase is realized in transport and thermodynamical quantities. It is manifested as a fluctuating Kondo-scattering–stabilized critical (gapless) fermionic spin-liquid metal. It shows ω/T scaling in dynamical electron scattering rate, a signature of quantum criticality. Our results offer a qualitative understanding of the $CePd_{1-x}Ni_xAl$ compound [2] and suggest a possibility of realizing the quantum critical strange metal phase in correlated electron systems in general.

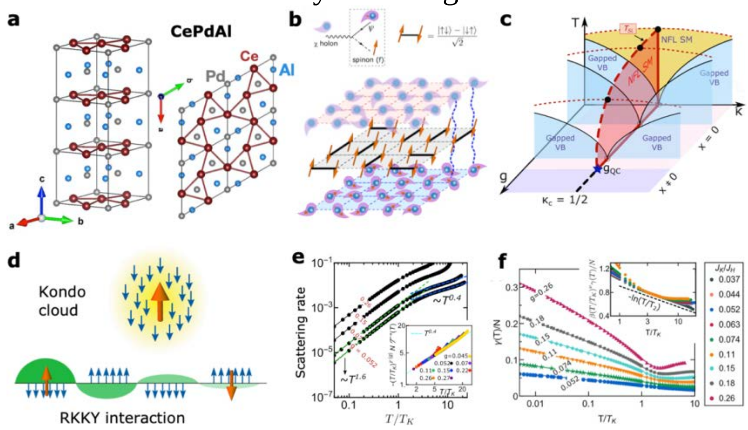

Figure 1*:* **a.** Crystal structure of CePdAl. **b.** Upper left: schematic representation for generating a composite holon (χ): a holon χ is generated by creating a spinon (f, orange arrow) and annihilating a conduction electron (ψ) through the Kondo interaction vertex. Upper right: schematic plot of a RVB spin-singlet bond. Bottom: Schematic plot of the gapless strange metal spin-liquid phase. **c.** Schematic phase diagram in terms of g, κ, and T of our model, where $g = J_K/J_H$ is defined as the ratio of the Kondo coupling J_K and the Heisenberg coupling J_H. **d.** Schematic representations of the Kondo effect and the RKKY interaction with T_K being Kondo scale. **e.** T-matrix as a function of dimensionless temperature T/T_K. Inset shows scaling of T-matrix. **f.** Specific heat coefficient as a function of T/T_K.

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[1] J. Wang, Y-Y Chang, and C.-H. Chung*, PNAS **119**, e2116980119 (2022).

[2] H. Zhao *et al.*, *Nat. Phys.* **15**, 1261–1266 (2019).