How spins become pairs: Composite pairing and magnetism in the 115 family of heavy fermion superconductors

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In the BCS paradigm, Cooper pairs form from well-defined quasiparticles, but the highest temperature heavy fermion superconductors pose a different problem. Here, the heavy electrons are forming as they pair, and the composite structure of the pair is as important as the forces holding it together. This issue is paramount in the 115 family of superconductors, which includes both $CeMIn_5$(M=Co,Ir,Rh) and its actinide cousins, $PuMGa_5$(M=Co,Ir,Rh) and $NpPd_5Al_2$. I will argue that the internal structure of the heavy fermion condensate necessarily involves two bosonic entities: a d-wave pair of quasiparticles on neighboring lattice sites, condensed in tandem with a composite pair of electrons bound to a local moment, residing within a single unit cell. These two components draw upon the antiferromagnetic and Kondo screening interactions to cooperatively enhance the superconducting transition temperature. I demonstrate this tandem pairing within a symplectic-N solution of the two-channel Kondo-Heisenberg model, showing that the two mechanisms couple linearly to enhance the transition temperature. Tuning the relative strengths naturally leads to a two dome structure, as seen in $Ce(Rh,Ir)In_5$. Additionally, the charge aspects of composite pairing lead should lead to sharp superconducting shifts in both the valence and the condensate quadrupole moment.

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