Emergence of superconductivity due to nuclear antiferromagnetic order

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Unconventional superconductivity often occurs in the vicinity of quantum critical points (QCPs) in antiferromagnetic heavy - fermion metals. However, no superconductivity has so far been observed near some of the canonical heavy - fermion QCPs, such as the one induced by a magnetic field (B) in $YbRh_2Si_2$, raising the question about the generality of this paradigm. Here, we will explore the possibility of reaching the quantum critical regime by sufficiently weakening the antiferromagnetic order through its coupling to nuclear spins at very low temperatures, instead of applying a pair - breaking magnetic field. To this end, we discuss results of magnetic and calorimetric measurements on $YbRh_2Si_2$ down to $T = 1$ mK (Ref. 1). They reveal the onset of a hybrid nuclear - electronic type of antiferromagnetic order dominated by the Yb - derived nuclear spins at T_A slightly above 2 mK and the subsequent development of superconductivity at $T_c = 2$ mK. The initial slope of the upper critical field curve, $B_{c2}(_T)$, at T_c is found to be as large as – $B'_{c2} \simeq 25$ T/K. This indicates that the effective charge - carrier mass must be of the order of several 100 mel, implying that the superconducting state is associated with the Yb - derived $4f$ - *electronic* rather than *nuclear* spins. Therefore, the theoretical possibility of superheavy - fermion superconductivity based upon an underlying nuclear Kondo effect can be ruled out. In conclusion, we ascribe the formation of Cooper pairs in $YbRh_2Si_2$ to the critical fluctuations associated with the unconventional, Mott - type, QCP of this antiferromagnet, which are revealed when the primary electronic order is diminished by the competing nuclear - dominated hybrid order. Our results demonstrate a new means to reach a field - induced QCP and provide further evidence that superconductivity in the vicinity of antiferromagnetic QCPs is a general phenomenon.

References:

[1] E. Schuberth, M. Tippmann, L. Steinke, S. Lausberg, A. Steppke, M. Brando, C. Krellner, C. Geibel, R. Yu, Q. Si and F. Steglich, Science 351, **485** (2016).