The superconducting pairing states in CeCu$_2$Si$_2$

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The prototype heavy fermion superconductor CeCu$_2$Si$_2$ exhibits very rich physical properties. It has been shown that two distinct superconducting states, one around an AFM QCP at low pressures and the other one around a weak first-order valence transition at high pressures, uniquely exist in the pressurized CeCu$_2$(Si/Ge)$_2$ [1]. In this talk, I will first briefly review the recent progress on the study of these two superconducting phases. Then I will focus on the superconducting pairing state of CeCu$_2$Si$_2$ at $p = 0$. Early measurements, e.g., specific heat and $\mu$ SR, revealed quite controversial behavior due to the limitations of experimental techniques and sample quality. In order to elucidate the nature of superconductivity in CeCu$_2$Si$_2$ and to investigate the interplay of AFM and superconductivity, we performed precise measurements of the magnetic penetration depth $\Delta\lambda(T)$ in high quality single crystals down to $T = 80$ mK. A linear temperature dependence of $\lambda(T)$ is observed in both A/S-type and S-type CeCu$_2$Si$_2$ below $T = 150$ mK, providing uncontroversial evidence for the existence of line nodes in the superconducting energy gap. [1] H. Q. Yuan et al., Science 302, 2104 (2003); Phys. Rev. Lett. 96, 047008 (2006).

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