Novel effect of critical valence fluctuations in unconventional superconductivity of Ce-based heavy fermions and related compounds

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Abstract: For this decade, our group has developed a theory for unconventional superconductivity in Ce-based heavy fermion systems CeCu$_2$(Ge,Si)$_2$ which exhibits anomalous enhancement of superconducting transition temperature $T_{sc}$ and non-Fermi liquid properties such as $T$-linear resistivity and huge enhancement of residual resistivity under pressure $P\sim P_c$ where the valence of Ce ion appears to change drastically [1,2]. Detailed experiments of CeCu$_2$Si$_2$ by Jaccard group at Univ. Geneve was explained in a unified way on a single assumption that the valence of Ce exhibits quantum critical valence transition or sharp crossover at $P\sim P_c$ [3].

After that, it turned out gradually that such a mechanism works also in other Ce-based heavy fermion systems such as CeTIn$_5$ ($T$=Co, Rh, Ir) which had been regarded as a typical example where only antiferromagnetic critical fluctuations play a crucial role [4]. A recent remarkable development is that the critical valence transition can be rather easily controlled by attainable magnetic field and explain a lot of anomalous properties of CeIrIn$_5$ and CeRhIn$_5$ [5]. This can resolve puzzles observed not only in these compounds but also in Yb-based heavy fermions such as YbXCu$_4$ ($X$=In, Ag, Cd, Au) and YbRh$_2$Si$_2$ which has been discussed as a typical example out of conventional understanding of antiferromagnetic quantum critical point.