Strongly correlated electrons in icosahedral Yb quasicrystals and approximants

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Keywords: quantum criticality, superconductivity, strongly correlated electron

Quasicrystals have been quoted as the 3rd solid because they possess long-range, quasi-periodic structures with diffraction symmetries forbidden to crystals. Due to the considerable progress since the discovery of quasicrystals in resolving their geometric structure, the quasicrystals are nowadays considered as a kind of crystal. Instead of extensive efforts on the electronic structure, no long-range ordering has been observed although spin-glass-like short-range orderings were observed in binary quasicrystals with localized moments. For an crystalline approximant, a phase whose composition is close to that of the quasicrystal and whose unit cell has atomic decorations similar to the quasicrystal, there are some reports showing ferromagnetic or antiferromagnetic orderings. However, there is no report of superconductivity in the quasicrystals and approximants to the best of our knowledge.

Recently, a new type of magnetic quasicrystal and approximant was discovered [1]: the Au-Al-Yb quasicrystal exhibits novel quantum critical behaviour as observed in Yb-based heavy fermion materials with intermediate Yb valence, while the Au-Al-Yb approximant shows heavy Fermi liquid behaviour [2]. Since the diverging behaviour of the magnetic susceptibility as $T \rightarrow 0$ was only observed in the quasicrystal, the quantum critical state might correspond to an electronic state unique to the quasicrystals, a critical state that is neither extended nor localized. Furthermore, quantum critical phenomenon of the Au-Al-Yb quasicrystal is remarkably robust against hydrostatic pressure. By contrast, the Au-Al-Yb approximant shows heavy fermion behaviour, very sensitive to hydrostatic pressure and quantum criticality of the approximant is induced by pressure. We speculate robust quantum criticality reflects unusual electronic state expected for strongly correlated electrons in quasicrystal. We will present quantum criticality of the Au-Al-Yb quasicrystal, and discovery of superconductivity by the substitution of Al atoms in Au-Al-Yb alloys [3].

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