4f electron-hole analogy in Tsai-type quasicrystalline approximants Au-Al-R (R = Ce and Yb)

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We have studied the effect of composition on the hybridization between 4f and conduction electrons, called c-f hybridization, in the cubic quasicrystalline approximants Au-Al-R (R = Ce and Yb) by the measurements of magnetic susceptibility \( \chi(T) \), electrical resistivity \( \rho(T) \), specific heat \( C(T) \) and thermoelectric power \( S(T) \).

Figure 1 shows the results of \( \chi(T) \) for \( \text{Au}_{x}\text{Al}_{86-x}\text{Yb}_{14} \) (51 \( \leq x \leq 64 \)), where the data for \( x = 51 \) are obtained from ref. [1]. Below 300 K, a Curie-Weiss behavior is observed only in \( x = 52 \) down to 150 K. The effective magnetic moment \( \mu_{\text{eff}} \), Weiss temperature \( \theta_{\text{W}} \) and \( T \)-independent term \( \chi_{0} \) are estimated as \( \mu_{\text{eff}} = 4.9 \ \mu_{\text{B}}, \ \theta_{\text{W}} = -160 \ \text{K} \) and \( \chi_{0} = -1.9 \times 10^{-3} \ \text{emu/mol-Yb} \), respectively. The magnitude of \( \chi \) decreases with increasing \( x \), indicating that the Yb valence of Au-Al-Yb varies from an intermediate state to divalent one due to the enhancement of c-f hybridization with increasing the concentration of gold.

On the other hand, all of \( \chi \)'s for \( \text{Au}_{y}\text{Al}_{84-y}\text{Ce}_{16} \) (62 \( \leq y \leq 70 \)) and \( \text{Au}_{76}\text{Al}_{10}\text{Ce}_{14} \) obey the Curie-Weiss law down to 50 K, as shown by \( \chi^{-1} \) vs \( T \) in fig. 2. The \( \mu_{\text{eff}} \) increases from 2.41 to 2.49 \( \mu_{\text{B}} \) with increasing \( y \). These values of \( \mu_{\text{eff}} \) are close to 2.54 \( \mu_{\text{B}} \) for a free Ce\(^{3+} \) ion, indicating the stable trivalency of Ce in Au-Al-Ce. The \( \theta_{\text{W}} \)'s are all negative, and the absolute values decrease from 13.5 K for \( y = 62 \) to 5.8 for \( \text{Au}_{76}\text{Al}_{10}\text{Ce}_{14} \). This feature indicates the suppression of c-f hybridization in Au-Al-Ce by the increase of Au, that is opposite to the \( x \) dependence of Au-Al-Yb. This contrast should result from the 4f electron-hole analogy between the strongly correlated Ce and Yb compounds.


![Fig.1: Magnetic susceptibility of Au-Al-Yb quasicrystalline approximants.](image1.png)

![Fig.2: Magnetic susceptibility of Au-Al-Ce quasicrystalline approximants.](image2.png)