The angle-resolved photoemission spectra of uranium based ferromagnets.

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Abstract

We investigate the spin-split and magnetization dependence of the 5f angle resolved photoemission spectra. For large values of the spontaneous magnetization, the model supports magnetic polaron excitations. We compare the results of our calculations with recent experimental results of Durakiewicz, Joyce and co-workers on related 5f compounds.

Key words: Ferromagnet, Photoemission, Quantum Critical Point, Magnetic Polaron
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A paramagnetic state close to a Quantum Critical Point (QCP), exhibits critical behavior that has been shown to be describable by Gaussian fluctuations about a mean-field fixed-point [1–3]. Therefore, it is reasonable to describe the excitations near the QCP in terms of a paramagnon-like picture [4,5], in which vertex corrections are ignored [6]. In fact, such a description also holds in the weakly-ferromagnetic state [7] where the Fermi-liquid description remains valid [8]. However, for stable strong ferromagnets, vertex corrections [9,6] do become important and it is expected that a magnetic polaron state may evolve.

The incoherent magnetic-fluctuations are known to renormalize the effective masses of the quasi-particles [4,5,7], but the Goldstone modes connected with the broken spin-rotational invariance [10,11] do not appreciably contribute to the mass enhancements. The spin-dependent mass renormalizations are defined in terms of the self-energies $\Sigma_\sigma(\omega, k)$ via

$$Z_\sigma(H) \;=\; 1 \;-\; \frac{\partial}{\partial\omega}\Sigma_\sigma(\omega, k_{F\sigma})\bigg|_{\omega=0} \qquad (1)$$

which should result in the flattening of the quasi-particle dispersion relation in the vicinity of the Fermi-energy. As shown in Fig. 1, the quasi-particle mass enhancements expected in measurements of the de Haas - van Alphen oscillations [12] are spin-split and strongly dependent on the magnetization M. It is found that the mass enhancements diverge logarithmically as $M \to 0$. It is also found that the mass enhancements satisfy the inequality $Z_\downarrow > Z_\uparrow$ showing that, for fixed M, the down-spin quasi-particles are heavier than the up-spin quasi-particles. The spin dependence of the mass enhancement is consistent with de Haas - van Alphen measurements [13] on doped CeB_6 and is consistent with the results of other approaches [14]. Therefore,

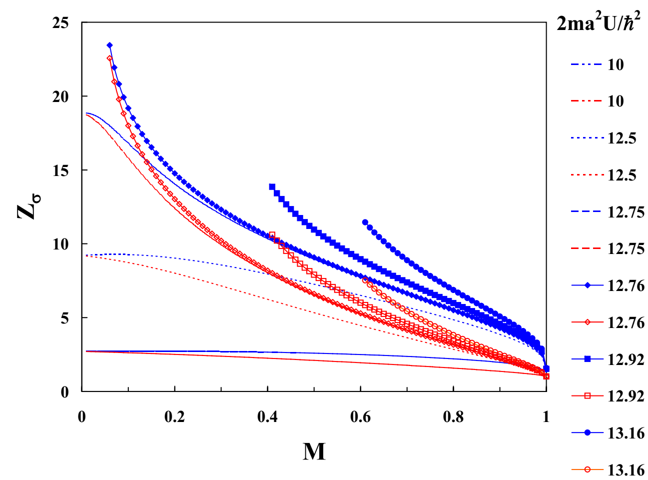

Fig. 1. The spin-dependent quasi-particle mass enhancements Z_σ as a function of the magnetization. In the unpolarized state, the quasi–particle masses are spin-independent, whereas they become spin-dependent in the presence of a magnetic field. In the ferromagnetic states, the down-spin enhancements are denoted by the filled symbols, and the up-spin enhancement by the open symbols.

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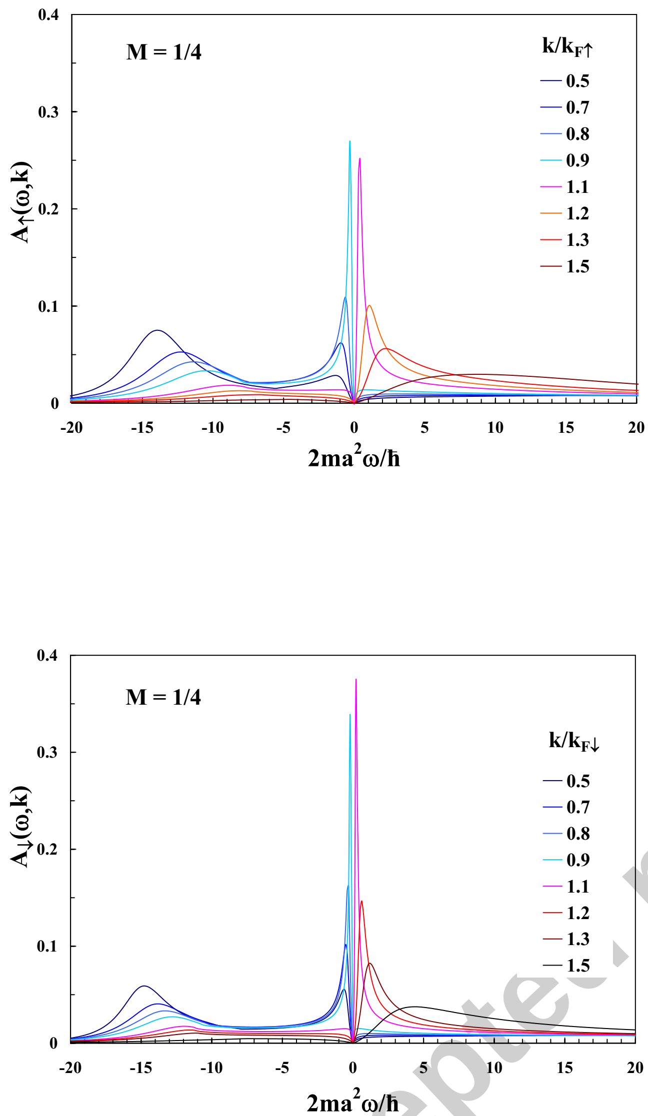

Fig. 2. The spin-dependent angle resolved photoemission spectra $A_\sigma(\omega, k)$ as a function of ω for various k values relative to the spin-dependent Fermi wave-vectors $k_{F\sigma}$.

one expects that the angle resolved photoemission spectra of ferromagnets should be spin-split and show a strong magnetization dependence of the quasi-particle peak. We have calculated the angle resolved photoemission spectra $A_\sigma(\omega, k)$ (shown in Fig. 2) for the one-band Hubbard model which shows that in addition to the narrowing of the quasi-particle peak at the Fermi energy, the spectrum shows a weak satellite structure below the Fermi-energy which disperses on varying the wave-vector k. The up-spin contribution to the angle integrated satellite intensity is significantly greater than the down-spin contribution, which is consistent with the majority spin contribution having the larger contribution to the total spectral weight. For increasing values of the magnetization, close to the limit of strong ferromagnetism, the many-body mass enhancements drops rapidly, since the phase space for incoherent spin fluctuations is dropping to zero. However, the branch of Goldstone modes extends of a large region of phase space, and represents the most significant many-body effect. It is in this limit, when vertex corrections are included, that the model exhibits magnetic polaron behavior [9,6].

The magnetization-dependence of the overall spectral width is in accord with the results of angle integrated photoemission experiments [15] of Durakiewicz *et al.* on a series of uranium based ferromagnets. For small values of the saturation magnetization, the width of the occupied portion of the quasi-particle band was observed to increase with increasing magnetization, in accord with the expectations of Stoner-theory. However, for a materials with larger values of the saturation magnetization, the overall width decreases which might be indicative of the formation of a magnetic polaron band.

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