Coherence in the non-Fermi-liquid of β-$YbAlB_4$ by ARPES

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Research on strongly-correlated electron systems has brought into light exotic state of matter, even breaking standard metallic behavior described by the Fermi-liquid theory. This breakdown takes place through a quantum phase transition, induced by tuning a parameter different from the temperature, as magnetic field, pressure or chemical doping. Open shell of the narrow ***f*-orbitals** can lead to such exotic physics by the competition between a **magnetic order** and **the Kondo-lattice** coherence. In an integral valence case, this physics is usually described by the Doniach picture. The energies of these two competing states depend on the same coupling constant *J*, tunable by an external parameter. It is when they become comparable, by a fine-tuning, that **quantum criticality** (QC) is observed.

With a **mixed-valence** of about **2.75** [1] and an unexpected scaling behavior [2], **β-$YbAlB_4$** presents an unconventional QC in sharp contrast with this last description. Adding this non-Fermi-liquid is a precursor to the first known superconducting state among ytterbium compounds, makes of **β-$YbAlB_4$** an intriguing and perfect system to study deviant behavior in strange metal. While other systems require a fine-tuning making it difficult, if not impossible, to probe them by photo-emission, QC in **β-$YbAlB_4$** develops in zero pressure and zero magnetic field **without any tuning** [3]. Besides being surprising, this fact allows **an unique opportunity to study the electronic structure in a quantum critical regime**.

Thus, the present work reports for the first time angle-resolved photo-emission measurements of **β-$YbAlB_4$**. Figure 1 presents dispersions close to the Γ point at **5 K** with the laser-ARPES setup ($h\nu$ = 6.994 eV) at the Institute for Solid State Physics (University of Tokyo). We can observe an **electron-like quasi-particle** (QP), crossing the Fermi level at k_F~ 0.1 Å^{-1}, binded at ~-4.5 meV, with a mass of **~10 times the free electron mass**, in accordance with quantum oscillations (QO) measurements [4].

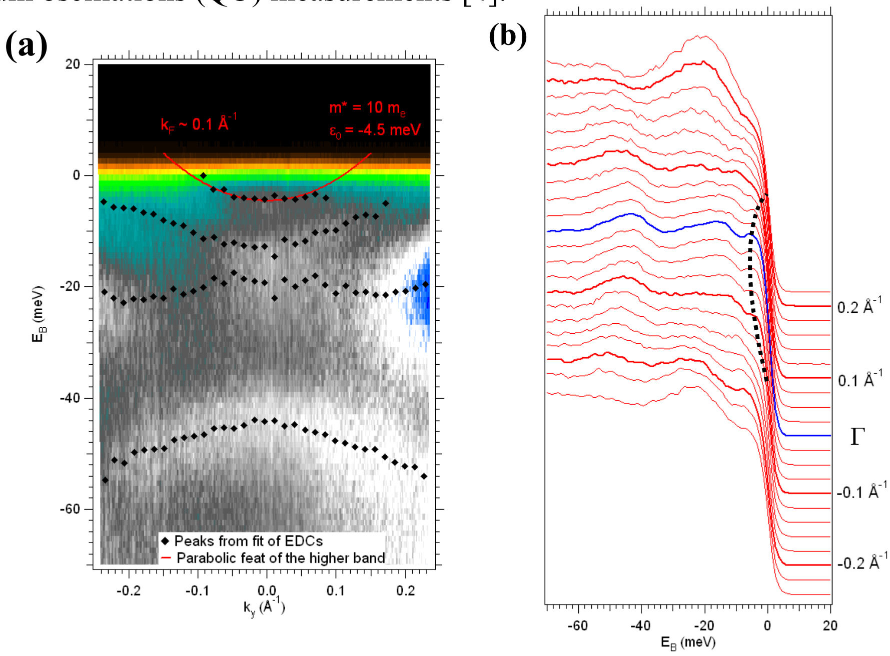

Figure 1 – (**a**) Binding energy versus momentum close to the Γ point. Black diamonds are peak positions. The red line is a parabolic fit to the e-like QP. (**b**) Energy distribution curves from (a). The dotted line is a guide to the eyes.

Wider ARPES mapping are compared with LDA calculations from [4] in figure 2. They both present two e-like bands crossing the Fermi level around Γ, and a similar dispersion at higher binding energy as shown by the green rectangles. These similarities support the **itinerant character of the *f*-electrons**. Still a major difference is to be noted : a **renormalization of about 5 to 10 of the masses**, as observed in figure 1, pointing at the strong electronic correlations.

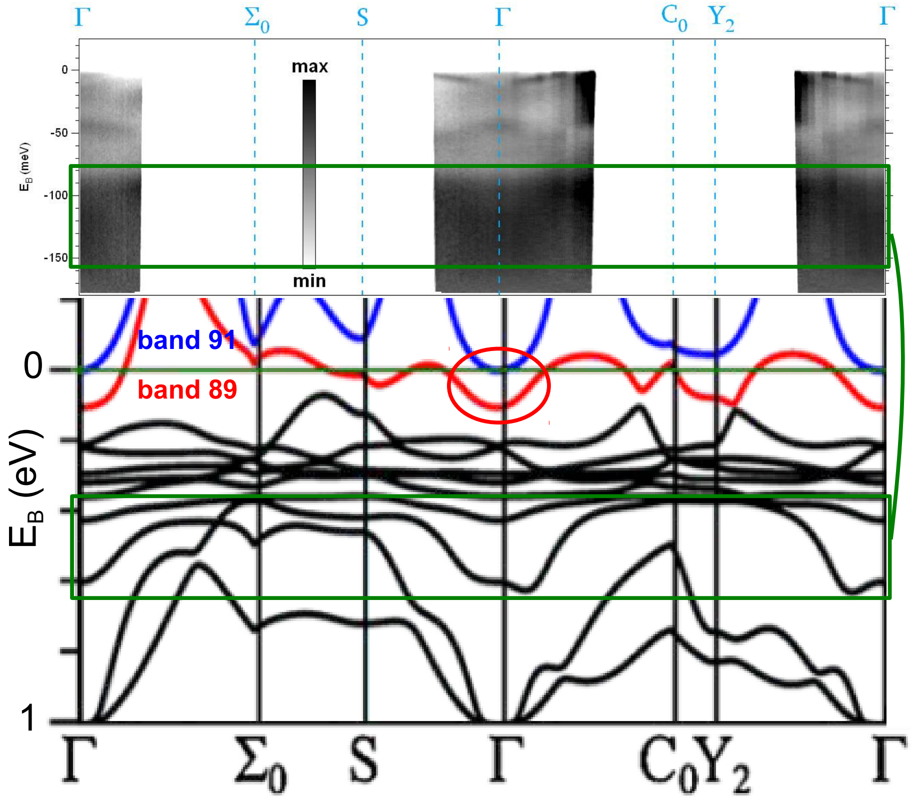

Figure 2 – Comparison between ARPES and LDA+SO calculation from [O'Farrell *et al.* PRL **102**, 216402 (2009)].

Modeling of the electronic structure close the Fermi level by the **hybridization** between **conduction electrons and 4*f*-levels** will be discussed together with its temperature dependence up to 60 K, revealing impacts of **two coherences** at $T^* \sim 8$ **K** and $T_{coh} \sim 40$ **K**, previously determined by transport [5,6].

[1] M. Okawa *et al.*, *Strong Valence Fluctuation in the Quantum Critical Heavy Fermion Superconductor β-YbAlB$_4$: A Hard X-Ray Photoemission Study* PRL **104**, 247201 (2010)

[2] Y. Matsumoto *et al.*, *T/B scaling of magnetization in the mixed valent compound β-YbAlB$_4$* JoP: Conf. Series **391**, 012041 (2012)

[3] Matsumoto *et al.*, *Quantum Criticality Without Tuning in the Mixed Valence Compound β-YbAlB$_4$* Science **331**, 316 (2011)

[4] E.C. O'Farrell *et al.*, *Role of f electrons in the Fermi surface of the heavy fermion superconductor β-YbAlB$_4$* PRL **102**, 216402 (2009)

[5] Y. Matsumoto *et al., Anisotropic heavy-Fermi-liquid formation in valence-fluctuating α-YbAlB$_4$* PRB **84**, 125126 (2011)

[6] E.C. O'Farrell *et al., Evolution of c-f hybridization and two-component Hall effect in β-YbAlB$_4$* PRL **109**, 176405 (2012)