

# The dual nature of 4f electrons in rare-earth intermetallics: ARPES view

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Rare-earth intermetallic compounds have taken a central place in condensed matter physics over the past three decades. Different types of magnetic order, unconventional superconductivity, magnetic heavy-fermion behavior and break-down of the Fermi-liquid properties are prominent examples of the astonishing low-temperature physics of these systems. Investigation of these phenomena is an intriguing task since a profound understanding of the

underlying mechanisms might enable to control these effects and to create new materials with tailored properties. Most of these properties are related to a delicate interplay between the partially filled 4f-shell and conduction electrons.

Our last experiments provide an important insight into the fine electronic structure near the Fermi level ( $E_F$ ) and the Fermi surface (FS) of  $\text{YbRh}_2\text{Si}_2$ . This compound has been in the focus of recent research for its unusual magnetic and Kondo properties and its close proximity to a quantum critical point. Here, we made the observation of crystal-electric field (CEF) splittings of a 4f state by means of  $k$ -resolved photoemission. This allowed us to disclose that interaction with extended valence bands can force the localized CEF-split 4f states to become dispersive and thus induce formation of hybridization gaps and  $E_F$  crossings in specific parts of the  $k$ -space. This can change

the ground-state symmetry as well as the occupancy, number, energy separation, energy order and degeneration of the CEF-split magnetic 4f states  $k$ -dependently, i.e. very different from the widely believed scenario based on non-interacting atomic-like 4f orbitals.

Finally, we got direct access to the FS of this system and: (i) detected its strong  $f$ -character, (ii) disentangled its topology and features reflecting  $f$ - $d$  coupling at the surface and bulk of the material, (iii) explored evolution of the iso-energy surfaces closely below the Fermi energy that indeed change dramatically at the meV range. These results create a solid platform to further attack on the outstanding low-temperature properties of rare-earth intermetallics including the Kondo phenomenon, heavy-fermion behavior and quantum-criticality.

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