Electronic structure of exotic states in some correlated-fermion materials: From hidden-order in URu2Si2 to spin-orbit coupled 2D electron gases in transparent oxides

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The physics of strongly interacting fermions is the common thread in several challenging open problems at all scales. For instance, such physics is involved in the description of compact nuclear and sub-nuclear matter, in the study of the primitive Universe and the symmetry breakings leading to today's observable cosmos, in ultra-cold atomic gases in optical lattices, or in electrons in a large class of solids in which low-dimensional or correlated behavior is present.

Specifically, in transition-metal oxides (TMOs) and f-electron systems, strong correlations lead to a wide realm of phase transitions and exotic, often poorly understood, states of matter showing remarkable macroscopic properties –such as high-temperature superconductivity, large magneto-resistance, multiferroicity, or photo-catalytic behavior. To understand such novel states of matter, harness the diverse functionalities of correlated-electron materials, and guide potential applications, it is essential to comprehend their microscopic electronic structure, which is ultimately responsible for their macroscopic behavior.

In this lecture, I will present an overview of current research on the electronic structure of two paradigmatic correlated-electron systems:

(i) The heavy-fermion URu2Si2. This material presents a puzzling 'hidden-order' phase transition at THO = 17.5 K, characterized by a large entropy loss and an energy gap of about 10 meV in the density of states at the Fermi level. However, since its discovery in the 1980's, the identification of the associated broken symmetry and order parameter are still a riddle. Following our observation of a heavy-electron Fermi-surface instability occurring at the transition [1], we recently studied the changes in electronic structure symmetries, and opening of a momentum-dependent energy gap, across the transition [2, 3]. I will show how these data provide a unified microscopic picture of the large entropy loss, gap opening and Fermi-surface reconstruction inferred from thermodynamic and magneto-transport measurements.

(ii) The two-dimensional electron gases (2DEGs) at the surface of transition-metal oxides. We recently discovered how to create 2DEGs at the surface of some insulating transparent oxides [4 – 6]. I will show that one can also tailor their electronic structure and symmetries by choosing the confining surface [7, 8]. Then, I will discuss our recent observation of a giant spin splitting, of 100 meV, of bands with opposite spin chiralities in the 2DEG at the surface of SrTiO3 [9]. These results show that confined electronic states at oxide surfaces can be endowed with novel, non-trivial properties that are not simple extensions of the bulk bands, and are promising for technological applications.

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