Strongly Correlated 5f Materials and Photoemission

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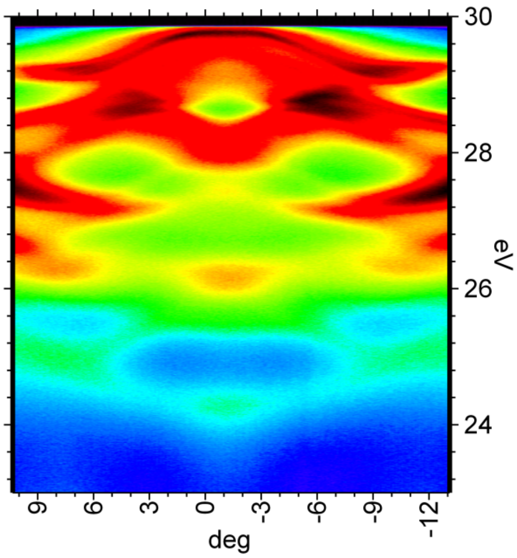
In condensed matter physics as one moves beyond an independent particle or one-electron model for understanding materials, interesting phenomena like Mott insulators, superconductivity, enhanced mass, and magnetic transitions are found. Uranium compounds are a fruitful field in which to explore strongly correlated properties of solids as the 5f electrons in the valence give rise to interesting bonding schemes and interactions. We have explored a range of uranium compounds that include the interesting properties of magnetism (USb_2, UTe), Mott insulators (UO_2), hidden order (URu_2Si_2), enhanced mass (UPd_2Al_3, UPt_3, UBe_{13}) and a seemingly boring compound, $UCoGa_5$ that now provides some interesting insight into intermediate coupling that may have broad application for a large number of strongly correlated systems. Many of these materials show multiple transitions such as UPd_2Al_3 that exhibits enhanced mass, magnetism, and superconductivity.



Using several different variants of photoemission we have explored a number of interesting uranium materials. The figure on right shows angle-resolved photoemission (ARPES) for URu_2Si_2. The ARPES data provides insight into the details of both the energy and crystal momentum for a material. This data set is taken at a photon energy of 34 eV to coincide with a high symmetry plane in reciprocal space. Additional insight is developed using resonance photoemission (RESPES) which isolate the 5f electron contribution to the valence electronic structure. Between ARPES and RESPES, one may construct a fairly detailed picture of the bonding and hybridization for these uranium materials. By adding temperature-dependent photoemission to the suite of tools, we can cross over phase transition boundaries as well as quantify electron-phonon coupling.

By combining photoemission with modeling and theory we advance the understanding of strongly correlated materials. We will show examples including determination of band magnetism in UTe, electron-phonon coupling in USb_2, f-p hybridization in UO_2, and intermediate coupling in $UCoGa_5$. Broadening the scope of interest beyond uranium materials, we will point to systematics in strongly correlated materials including Ce and Pu counterparts for a number of the above compounds. The overarching principle controlling strongly correlated behavior in these materials is f-electron bonding and hybridization. Photoemission, in its various forms, provides an outstanding opportunity to elucidate the nature of f-electron bonding and hybridization.

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