Hard and soft RIXS investigations of correlated and topological phases in *f*-electron materials

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Due to strong scientific interest in high-temperature superconductivity where it is known to exist and the large exchange energy scales in 3*d* materials classes, a natural historical progression of the resonant inelastic X-ray scattering (RIXS) technique has left many stones unturned further down the periodic table. Nowadays, energy resolution achievements motivated by light metal science has positioned us to turn this developing technique on a broader range of materials.

f-electron materials host interesting phase competition and have exploded as an arena for materials which may hold nontrivial electronic topology. Using current-generation synchrotron techniques and facilities in the US and abroad, our collaboration has shown that useful signal can be reaped in the context of Yb- and Sm-based materials in the soft and hard X-ray regimes. In particular, we present recent and new results on an exemplary material $YbInCu_4$, which shows a first-order phase valence transition where the order parameter may be characterized as the *f*-count. This temperature-driven instability has been discussed in connection to the Kondo valence collapse scenario, but the relative insensitivity of volume to valence change has left an open hole in this explanation. A density-of-states effect has long been hypothesized, and only recently have we used RIXS to present strong evidence of a quasi-gap in the itinerant state density, as probed through the Yb 5*d*-derived bands using L_3-edge (3*p*->5*d*) RIXS. This quasigap was not observed using optical spectroscopy and cannot be observed using photoemission, due to the known surface-related phenomena in this class of materials. We will also present a first look using related approaches to Sm-based materials.

Separately, we also present $M_{4,5}$-edge (3*d*->4*f*) RIXS spectra on the same material and show that a completely disjoint set of information can be determined by exciting primarily 4*f* states in the "direct" RIXS process. Here, we see spin-orbit excitations as well as signature of the hybridization gap detected in optical experiments, but now with valence and orbital selectivity and momentum control.

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References:

[1] I. Jarrige, A. Kotani, H. Yamaoka, N. Tsujii, K. Ishii, M. Upton, D. Casa, J. Kim, T. Gog, and J. N. Hancock, *Kondo interactions from band reconstruction in* $YbInCu_4$, Physical Review Letters, 114, 126401 (2015)
[2] J. N. Hancock and I. Jarrige, *The promise of resonant inelastic X-ray scattering for f-electron materials*, Journal of Magnetism and Magnetic Materials, 400, 41 (2016).
[3] J. N. Hancock, T. McKnew, Z. Schlesinger, J. L. Sarrao, and Z. Fisk, *Kondo Scaling in the Optical Response of YbIn1−xAgxCu4* Physical Review Letters 92, 186405 (2004)
[4] S. R. Garner, J. N. Hancock, Y. W. Rodriguez, Z. Schlesinger, B. Bucher, Z. Fisk, J. L. Sarrao, *Optical Study of the Electronic Phase Transition of Strongly Correlated YbInCu4*, Physical Review B 62, R4778 (2000)