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Defects in Heavy-Fermion Materials: Unveiling Strong Correlations in Real Space[1]

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Heavy-fermion materials exhibit a plethora of puzzling phenomena which are believed to arise from the competition between Kondo screening and antiferromagnetic ordering. The microscopic origin of these phenomena, such as the non-Fermi-liquid properties observed in the quantum critical region, is still a topic of debate. Recent groundbreaking scanning tunneling spectroscopy (STS) experiments [1-4] have shed new light on this debate by providing important insight into the electronic and magnetic structure of heavy fermion materials. In this talk, I review some recent progress made in our theoretical understanding of the differential conductance, dI/dV and the resulting quasi-particle interference (QPI) patterns [5-7], observed in these experiments. In particular, I will demonstrate that defects in heavy-fermion materials provide an unprecedented opportunity to disentangle electronic correlations arising from Kondo screening, and antiferromagnetic correlations between the magnetic moments by inducing perturbations in the electronic and magnetic structure that exhibit characteristically different spatial patterns. The spatial extent of these perturbations grows with the strength of the magnetic interactions, and thus directly reflects the degree of correlations [5]. In addition, I show that non-magnetic defects (Kondo holes) in heavy fermion materials can give rise to the formation of an impurity bound. Our prediction of spatial hybridization oscillations and the formation of an impurity bound state were recently confirmed by STS experiments [4]. Moreover, I will demonstrate that QPI spectroscopy, utilizing spatial oscillations in the LDOS induced by defects, does not only provide important insight into the electronic structure of heavy fermion materials, but also in the entanglement of electronic and magnetic states [6,7]. Finally, the strongly correlated nature of heavy-fermion materials leads to a highly non-linear quantum interference between defects, and the creation of order from disorder. These results provide unique insight into the spatial complexity of heavy fermion materials.

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