

# Anisotropic Kondo pseudo-gap and Hidden Order in URu<sub>2</sub>Si<sub>2</sub>

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While the Kondo effect is well understood for single Kondo impurity systems, for Kondo lattice systems containing rare-earth elements (for which the Kondo impurities are realized by local  $f$  electron orbitals), it remains more puzzling and exhibits surprising phenomena [1, 2]. For instance, anisotropic orbital-dependent hybridization may have significant consequences for the entire phase diagram of these systems [3]. The heavy fermion URu<sub>2</sub>Si<sub>2</sub> that exhibits one of the most mysterious quantum states of matter below 17.5 K, the so-called “hidden order” (HO) state, is a relevant example of metallic Kondo lattice systems for which exotic Kondo effects may play a significant role in the appearance of the HO. Despite over three decades of intensive research, no consensus has yet been found regarding the microscopic nature of the HO. Recent efforts have revealed important information on this problem, including the A<sub>2g</sub> signatures of the HO state as seen by Raman spectroscopy [4, 5]. While the URu<sub>2</sub>Si<sub>2</sub> “story” appears close to being resolved, some key issues remain, such as the inter-relation between the Kondo coherent regime and the HO state.

Here, we present a Raman polarized study of the Kondo physics of single crystalline URu<sub>2</sub>Si<sub>2</sub> [6]. We observe a symmetry dependence of the electronic Raman response through the Kondo crossover (100K), with a Kondo pseudo-gap developing mainly in the E<sub>g</sub> symmetry, highlighting the presence of strong anisotropy. Thanks to Raman vertex calculations (in agreement with our observations), we provide the  $k$ -space dependence of the Kondo pseudo-gap showing a  $d$ -wave like geometry. Such anisotropy has not been predicted and has never been taken into account in theoretical models until now. Moreover, the Kondo pseudo-gap opening is found to be reinforced at low temperatures, within the HO state, suggesting that Kondo physics may play an important role as a precursor to the HO state. Finally, the anisotropy of the pseudo-gap is similar in form to that proposed for the chiral  $d$ -wave (E<sub>g</sub>) superconducting state that appears below  $T_c = 1.5$  K.

[1] Yang et al., PNAS 109, E3060 (2012)

[2] Lonzarich et al., ROPP 80, 024501 (2017)

[3] Weber et al., PRB 77, 125118 (2008)

[4] Buhot, et al., PRL 113, 266405 (2014)

[5] Kung et al., Science 347, 1339 (2015)

[6] Buhot et al., submitted (2018)