ESRF	**Experiment title:** **Experimental test of a scaling property of the Kondo problem by RIXS**	**Experiment number:** HE1146
Beamline: ID16	**Date of experiment:** from: 13/9/2001 to: 18/9/2001	**Date of report:** 26/2/2002
Shifts: 15	**Local contact(s):** Abhay Shukla, Gyorgy Vankò	*Received at ESRF:*

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Report:

The spectroscopic determination of the 4f occupancy – and of the valence - in Ce or Yb compounds is greatly hindered by the surface sensitivity of conventional probes like photoemission. Here we show that it is possible to use Resonant Inelastic X-ray Scattering (RIXS) to obtain reliable, bulk-sensitive estimates of these important quantities.

We studied $YbInCu_4$ and $YbAgCu_4$, two model intermediate-valence systems. $YbInCu_4$ exhibits (at $T_V = 42$ K) a first order valence transition, from 2.96 ($T>T_V$) to 2.83 ($T<T_V$). $YbAgCu_4$ is a typical 'Kondo' material, with a characteristic Kondo temperature T_K=60-100 K. At BL ID16 we measured temperature-dependent high-resolution absorption (XAS) spectra in the Partial Fluorescence Yield (PFY) mode, and RIXS spectra at the Yb L_3 ($2p_{3/2}$) edge. In both cases, the $L_{\alpha 1}$ (3d-2p) emission was recorded.

The ground state of $YbInCu_4$ and $YbAgCu_4$ is a coherent superposition of the Yb^{2+} ($4f^{14}$) and Yb^{3+}($4f^{13}$) configurations. The fingerprints of both configurations are visible in the XAS spectra as distinct features (inset of Fig. 1). They correspond to the final states $2p^5 4f^{14} d^{n+1}$ and $2p^5 4f^{13} d^{n+1}$, separated by 7 eV by the strong 4f-core hole Coulomb interaction in a RIXS experiment. Distinct 2+ and 3+ features are also observed in the RIXS spectra, following the decay of the XAS final states. The intensity of the signal from the minority Yb^{2+} configuration can be greatly enhanced when the primary energy is tuned to the maximum of the corresponding Yb^{2+} feature in XAS spectrum (Fig. 1).

In this on-resonance condition we have studied the temperature dependence of the RIXS spectra. The large intensity increase of the divalent peak allowed us to record it as a continuous function of temperature by detecting the emitted radiation in a 1.5 eV wide fixed energy window. Its intensity is proportional to (1- n_h), where n_h is the number of f-holes (n_h = 0 for Yb^{2+}, n_h = 1 for Yb^{3+}). In $YbInCu_4$ (Fig. 2) the intensity of the Yb^{2+} component drops at T_V, reflecting the sudden change of valence. In $YbAgCu_4$ (Fig. 3) the temperature dependence of the divalent peak exhibits a continuous decrease with increasing temperature, as predicted by the Anderson Impurity Model (AIM). The experimental curve is reproduced extremely well by an AIM calculation assuming a Kondo temperature T_K = 70 K.

This result demonstrates that RIXS is a valuable spectroscopic probe of intermediate valence and covalence. We foresee interesting applications in other strongly correlated systems, including under extreme conditions of pressure and magnetic fields.

C. Dallera, M. Grioni, A. Shukla, G. Vankò, J.L. Sarrao, J.P. Rueff, D.L. Cox, "Evidence of a spectroscopic Kondo scale in ytterbium compounds", submitted to PRL.

Figures and captions:

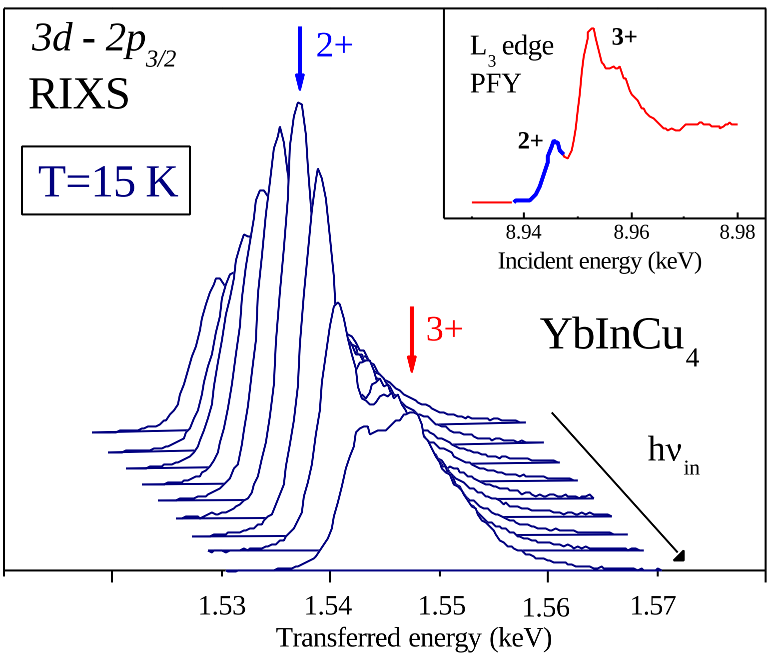

Figure 1. RIXS spectra of ytterbium in $YbInCu_4$ below the transition temperature (T_V = 42 K). The incident energy was scanned in the region of the Yb^{2+} signal (thick part of the Partial Fluorescence Yield absorption curve in the inset). At its resonance the divalent peak dominates the spectrum.

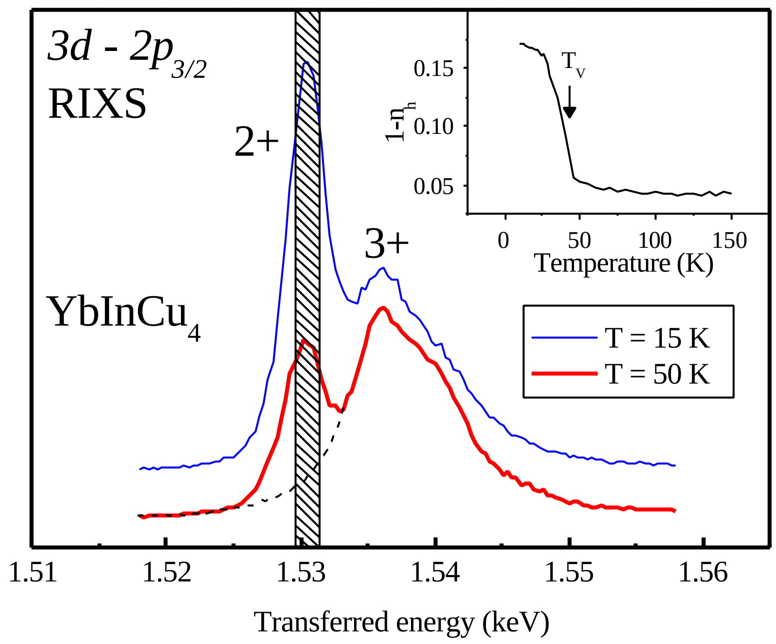

Figure 2. Ytterbium Lα_1 RIXS spectra in $YbInCu_4$ excited at the maximum of the Yb^{2+} resonance of Figure 1 ($h\nu_{in}$ = 8945 eV). The small change of valence (Δn_h = 0.13) results in a large change of the divalent peak intensity. The inset shows the continuous intensity evolution of the number of *f* holes, measured by monitoring the shaded area indicated on the RIXS spectra.

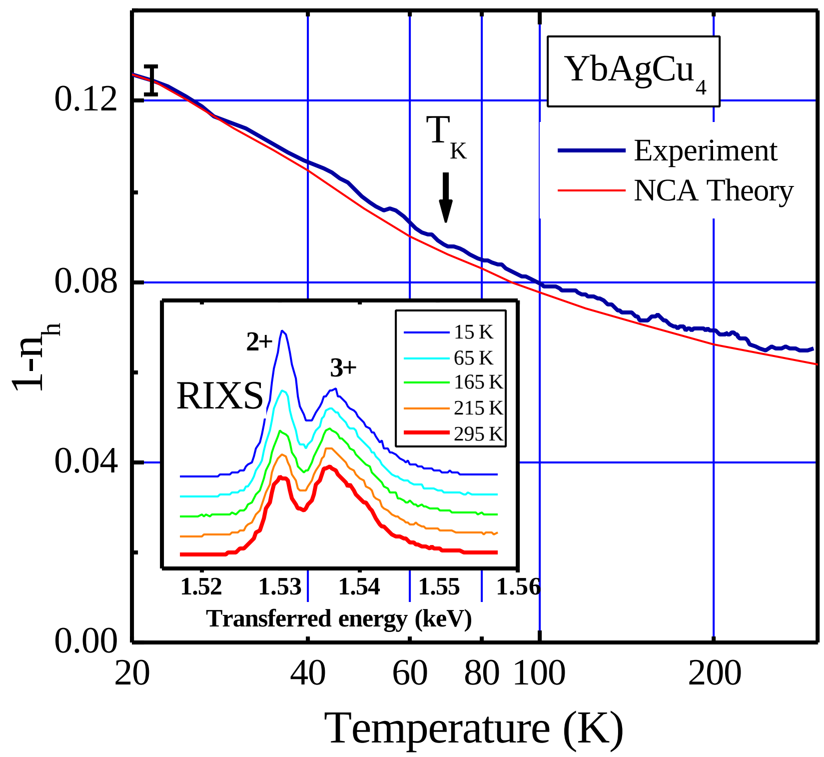

Figure 3. Temperature dependence of the Yb^{2+} RIXS signal of $YbAgCu_4$, measured as in Fig.2. The experimental signal has been normalized to the incident photon intensity, and a constant term from the tail of the Yb^{3+} signal has been subtracted. The measured intensity has been converted into (1-n_h) values by adopting the XAS value n_h(15 K)=0.87. Raw RIXS spectra at representative temperatures are shown in the inset.