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Names and affiliations of applicants (* indicates experimentalists):

Claudia DALLERA* – INFM-Dipartimento di Fisica del Politecnico di Milano, Italy
Emilia ANNESE* – Lab. TASC INFM in Area Science Park, S.S. 14 Km 163.5, 34012 Basovizza, Trieste, Italy
Marco GRIONI* - Institut de Physique des Nanostructures, Ecole Polytechnique Fédérale de Lausanne, Switzerland
Georg KNEBEL*, Jean-Pierre SANCHEZ* - DRFMC/SPSMS CEA Grenoble, France
Alessandro BARLA* - IPCMS/GEMME Strasbourg, France
Matteo D'ASTUTO*, Jean-Claude CHERVIN * - Physique des Milieux Condensées, Univ. Pierre et Marie Curie, Paris

Report:

This experiment was the continuation of experiment HE1798 "Valence Investigation of Heavy Fermions near a Quantum Critical Point". The aim of the two experiments was the investigation of the electronic changes driven by pressure and temperature on the Yb heavy fermion compounds $YbNi_2Ge_2$ and $YbRh_2Si_2$. During the beamtime allocated to proposal HE1789 we studied separately the effect of pressure and temperature. In the new beamtime we investigated P and T simultaneously. This was possible thanks to a dedicated setup: the low T, high P equipment was provided by the *Laboratoire de Physique des Milieux Condensés* (Paris). It consists of a liquid He flow refrigeration system for the Diamond Anvil Cell. The pressure is changed through a gas membrane, and is measured *in situ* by ruby luminescence. With this setup it is possible to reach the lowest temperature of 20 K and the highest pressure of about 20 GPa.

In the experimental report HE1789 we already outlined the main features of the physics of $YbNi_2Ge_2$ and $YbRh_2Si_2$. These are here summarized and the results of the recent experiments are given.

The ground state properties of the Kondo lattice systems $YbNi_2Ge_2$ and $YbRh_2Si_2$ depend on the coexistence of Kondo and RKKY interaction. The competition between the two interactions, related in opposite ways to the coupling of nearly localized *f* moments and extended conduction electrons, leads these systems towards a magnetic instability and eventually to a magnetic quantum critical point.

Changes in the electronic properties of these compounds have been investigated by studying their resistivity, specific heat and magnetic measurements [for instance in Refs. 1,2]. It is possible to gain direct insight into electronic interactions by investigating how the hybridization strength is affected by pressure and temperature. As proved by some experiments in the recent years, Resonant Inelastic X-Ray Scattering (RIXS) is a well suited technique to detect even small changes in the electronic structure of mixed-valence compounds [3]. Moreover, when it is performed in the hard X-ray energy range, RIXS allows to study samples that are in diamond anvil pressure cells. The results of the new measurements are reported in the figures below .

We measured the $L\alpha_1$ (*3d-2p*) RIXS excited along the L_3 edge of ytterbium, as a function of pressure, both at room temperature and at the lowest reachable temperature (the room temperature data had been measured during

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[1] J. Custers et al., Nature **424**, 524 (2003). S. Paschen et al., Nature **432**, 881 (2004).
[2] G. Knebel et al., Journal of Physics: Condensed Matter **13**, 10935 (2001).
[3] C. Dallera et al., Phys. Rev. Lett. 88, 196403 (2002). C. Dallera et al., Phys. Rev. B **68**, 245114 (2003). Report HE1593 on SmS under pressure

Exp. HE1798 and were repeated for reference). Figures 1A and 1B refer to $YbRh_2Si_2$, Figures 2A and 2B to $YbNi_2Ge_2$. The main panels present RIXS spectra as a function of pressure, excited at the resonance of the divalent configuration of ytterbium. Spectra were normalized to the peak of *Yb3+* for comparison. The insets contain the Partial Fluorescence Yield spectra.

We give here some comments about $YbRh_2Si_2$. As already expected from the measurements of the previous experiment, at low temperature a strong increase of the divalent component is seen. This is consistent with the sudden drop in resisitivity observed in Ref. 4: a decrease of resistivity indicates the formation of a coherent state. Our spectroscopic results allow to associate it to the stronger hybridization of *4f* and *5d* states, that leads to a diminution of the *4f* occupation number. At increasing pressure Ytterbium becomes completely trivalent above 10 GPa at low temperature, ie. its configuration will be $4f^{13}$, with a single unpaired spin in the *4f* shell. Consistently, magnetic (Mössbauer) measurements [5] reveal the appearance of magnetic moments above 10 GPa at low temperature.

The detailed analysis of these results will allow to extract the precise *4f* electron count in a wide region of the (P,T) space and thus to relate the electronic structure to transport and magnetic properties.

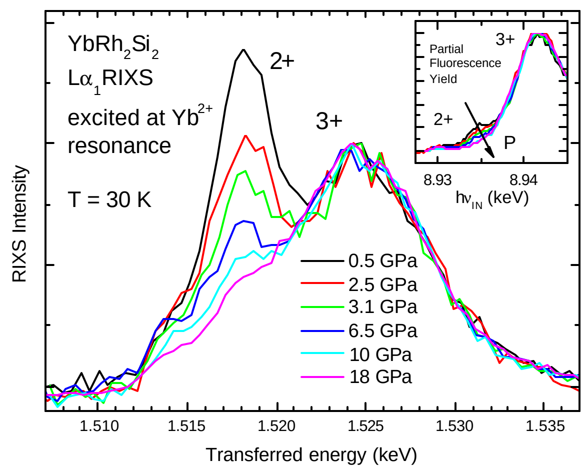

Fig. 1A. RIXS spectra of $YbRh_2Si_2$ vs. P at 30 K.

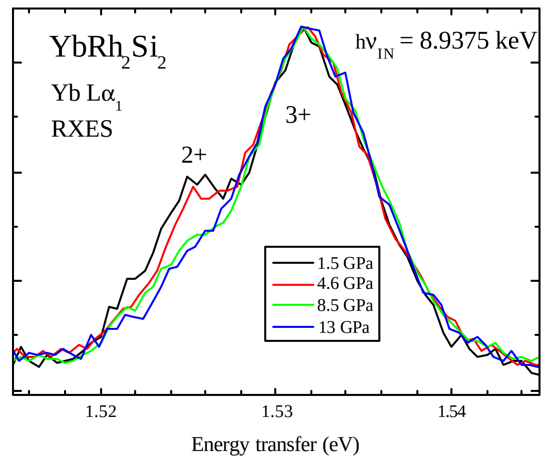

Fig. 1B. RIXS spectra of $YbRh_2Si_2$ vs. P at RT.

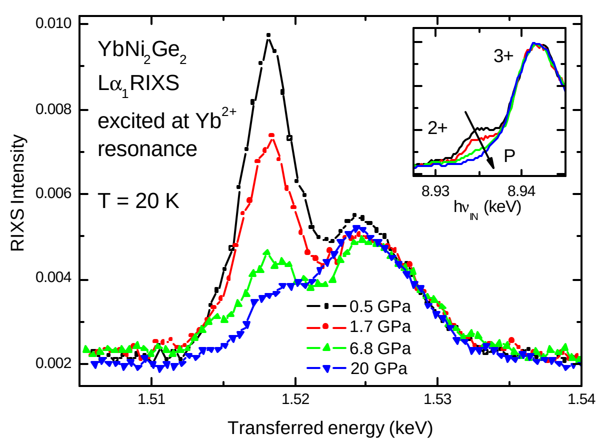

Fig. 2A. RIXS spectra of $YbNi_2Ge_2$ vs. P at 30 K.

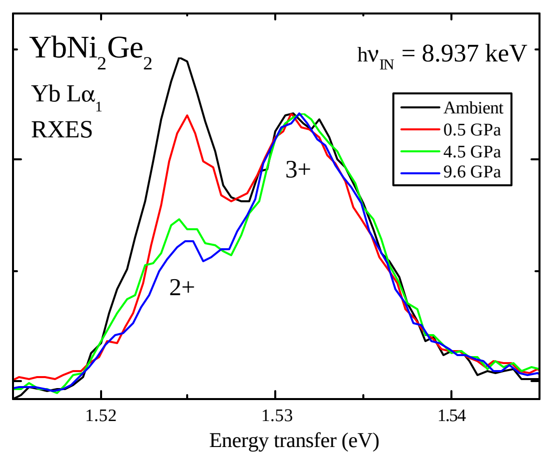

Fig. 2B. RIXS spectra of $YbNi_2Ge_2$ vs. P at RT.

[4] O.Trovarelli et al., PRL 85, 626 (2000)

[5] J. Plessel et al., PRB 67, 180403R (2003)