PhD opening in Nanoscience:

Quantum critical Kondo lattice of molecular spins probed by scanning tunneling microscopy

Supervisors : Prof. Jean-Pierre Bucher and Prof. Mario Ruben

Karlsruher Institut für Technologie (KIT) and Université de Strasbourg (IPCMS)

Contact: jean-pierre.bucher@ipcms.unistra.fr

In the quest for quantum materials, the phenomenon of quantum criticality provides intriguing new perspectives since electrons re-organize themselves into a new stable phase of matter when their ground state becomes unstable against magnetism. While the vast majority of studies have been conducted on 3D bulk materials [1] this PhD project aims at studying quantum criticality in lower dimensions, where potentially larger fluctuations are expected. More precisely, we would like to study what physics emerges when going from a single Kondo impurity (0D) that exhibits a quantum entanglement of a single atomic spin with the conduction electrons of the substrate, to a 2D lattice of spins (Kondo lattice). In order to investigate the quantum criticality on surfaces, we will use the self-organization of spin centers of magnetic atoms dressed by ligands, so-called single molecule magnets [2,3]. Molecular manipulation with the tip of a scanning tunneling microscope (STM) will provide additional means to fabricate molecular clusters for controlling the entanglement of elementary units [2]. The electronic/magnetic properties of such low dimensional systems will then be investigated on a local basis by STM, allowing a step-by-step study of the transition between 0D, 1D and 2D structures.

By means of STM conductance mapping we have recently shown the evidence for a Kondo screening of the *4f*-electrons of $TbPc_2$ molecule magnets on surfaces [3]. In this project we now consider tuning the hybridization between 4*f*-orbitals and itinerant electrons of the substrate by means of a targeted synthesis of the lanthanide complexes. Substrates as well will be chosen carefully as a mediator for the indirect spin-spin interaction, providing an ideal playground to destabilize the Fermi-liquid state towards an antiferromagnetically ordered ground state at the quantum critical point. The measurements will be done in ultrahigh vacuum by means of a dedicated low temperature (LT)-STM equipped with a vector magnetic field. The candidate will be involved in an ambitious joint project between Strasbourg and Karlsruhe.

[1] P. Coleman et al., *Nature*, **433**, 226 (2005); S. Sachdev, B. Keimer, *Phys. Today*, **64**, 29 (2011); F. Steglich, *Journal of Physics* : Conference Series **400**, 022111 (2012); P. Gegenwart et al., *Nature Physics*, **4**, 186 (2008).
[2] A. Amokrane et al., *ACS Nano*, **11**, 10750 (2017). R. Tuerhong et al., *J. Phys. Chem. C* **122**, 20046 (2018).
[3] R. Barhoumi et al., *Nanoscale*, **11**, 21167 (2019).

The candidate's profile: We are looking for highly motivated candidates with a master degree in physics. The candidate for this PhD project must have a strong background in condensed matter and magnetism. Experience with ultrahigh vacuum and STM is welcome and proficiency in English is required. Interested candidates are invited to send a CV, a motivation letter, grades and ranking. The candidate will be selected in agreement with the application procedure of the QUSTEC PhD school.