## PhD Opening in Nanoscience

# Quantum Criticality and Molecular Entanglement

**Position:** 3 year Ph.D. funding (France-German project).
**Place**: Université de Strasbourg, IPCMS and Karlsruhe Institut für Technologie, INT
**Deadline for applications:** May the 31st 2019.

In today's 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 solid-state materials [1] this 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 involving a unique atomic spin, to a 3D lattice of spins (Kondo lattice) [2]. In order to investigate the quantum criticality on surfaces, we use the self-organization of spin centers of magnetic atoms dressed by ligands [3,4]. The electronic/magnetic properties of low dimensional systems are probed in a unique way by scanning tunneling microscopy/spectroscopy (STM/STS), allowing a step-by-step study (i.e. atom by atom) of the progressive transition between 0D, 1D and 2D. Furthermore, molecular manipulation with the STM tip [3] is used to fabricate molecular clusters for a controlled quantum entanglement of elementary units. Substrates will be chosen carefully as a means to vary the nature of the indirect spin-spin interaction [4], providing an ideal playground to study quantum criticality. For a better understanding of the underlying many body physics, the experimental efforts will be supported by theoretical calculations.
For this project a dedicated low temperature (LT) -STM equipped with a vector magnetic field will be used to accurately address the local electronic properties of single molecules on surfaces. Spin excitation spectroscopy and Kondo mapping at every point in space will be the main (but not exclusive) tools to follow their magnetic behavior. The measurements are carried out in ultrahigh vacuum to ensure a clean and reproducible experimental environment.
The candidate will participate in an ambitious multi-partner project with the group of Prof. Jun Onoe (U-Nagoya). The molecular magnets are synthesized in the group of Prof. M. Ruben (INT, Karlsruhe Institute für Technologie). Theoretical support is provided by the team of Dr. M. Boero (IPCMS).

[1] P. Coleman et al., *Nature*, 433, 226 (2005); P. Coleman, *Nature Materials*, 11, 185 (2012); F. Steglich, *Journal of Physics* : Conference Series 400, 022111 (2012).
[2] M.N. Leuenberger, D. Loss, *Nature* , 401, 789 (2001).
[3] A. Amokrane, S. Klyatskaya, M. Boero, M. Ruben, J.P. Bucher, *ACS Nano*, 11, 10750 (2017).
[4] R. Tuerhong, F. Ngassam, S. Watanabe, J. Onoe, M. Alouani, J.P. Bucher, *J. Phys. Chem. C* 122, 20046 (2018).

**Supervisors**: Prof. Jean-Pierre Bucher (Unistra), Prof. Mario Ruben (KIT, Karlsruhe)
**Keywords**: Molecular electronics, Quantum materials, Scanning tunneling microscopy/ spectroscopy.
**Candidate's profile:** We are looking for a highly motivated candidate with a scientific master degree. He/she should have a background in physics and a good knowledge in material science, taste and skills for experimental work. The candidate should be fluent in scientific English. Interested candidates are invited to send a CV, a motivation letter, grades and ranking along with two supporting letters to: jean-pierre.bucher@ipcms.unistra.fr Tel: 03 88 10 70 96