PhD proposal

Beyond the Standard Model (of Condensed-Matter Physics):
Electronic Structure of the Metal-Insulator Transition

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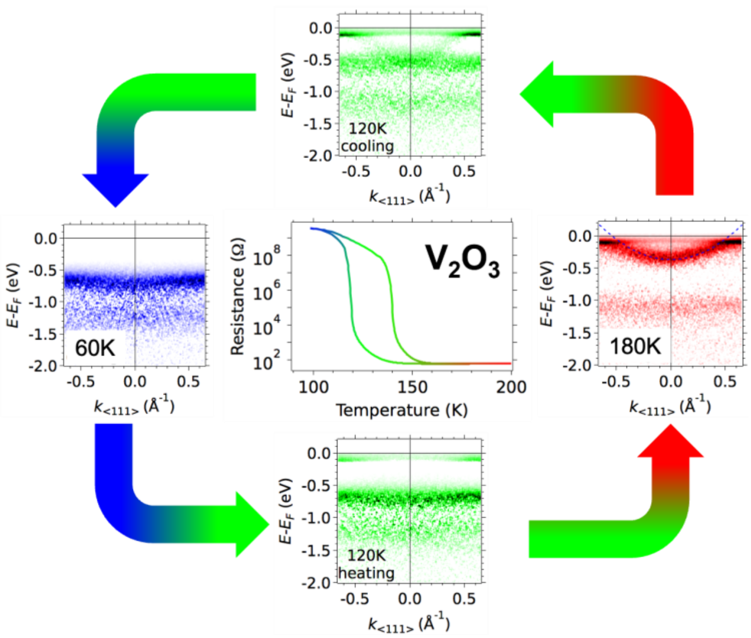
The physics of strongly interacting fermions is the common pillar of several challenging open problems at all scales. One finds it in the description of quarks and gluons in compact nuclear and sub-nuclear matter, in neutron stars, or in the behavior of electrons in a large class of solids, also known as 'quantum materials', in which strong electron interactions are present. For instance, in transition-metal oxides electron correlations are so strong that the slightest perturbation can radically change their ground state. These materials display thus numerous classical and quantum (at zero temperature, as a function of an external parameter) phase transitions and exotic states of matter showing remarkable properties, such as high-temperature superconductivity, large magneto-resistance, or metal-to-insulator transitions. The resulting broken symmetries and electronic collective phenomena are among the most puzzling problems of modern physics.

To understand these exotic states of matter, we use angle-resolved photoemission spectroscopy (ARPES), a technique that directly images the electronic eigen-energies of a solid. During this PhD, you will use ARPES to explore in detail the evolution of the electronic structure and broken symmetries induced by temperature, doping and strain across the archetypal 'metal-to-insulator' (MIT) transition. This first-order phase transition is observed in several vanadium oxides. In fact, according to the Bloch theory, metal or insulator are mutually exclusive states of matter. The very existence of a metal-to-insulator transition shakes the foundations of such a well-tested model! We have recently imaged how the electronic structure of V_2O_3 changes across its temperature-induced MIT [M. Thees et al, Science Advances 7, eabj 1164 (2021)]. We would like now to use strain to measure how the electronic structure changes across the "pressure-induced" transition, which is purely electronic (i.e., without structural or magnetic transitions). We would also like to image, using micro-ARPES and nano-ARPES, the electronic states and their evolution across the MIT in individual metallic or insulating domains.

The experiments will be performed at several synchrotrons around Europe (France, Germany, Spain, Sweden, among others), Japan (Tsukuba, Sendai), and China (Shanghai). You will also participate to the assembly and operation of a lab-based high-resolution ARPES system coupled to a chamber for thin-film growth.



Changes of the electronic structure of V_2O_3 near the Fermi level when cooling and warming across its metal-to-insulator transition. The inset shows the corresponding change in resistivity. Adapted from M. Thees et al, Science Advances 7, eabj 1164 (2021).