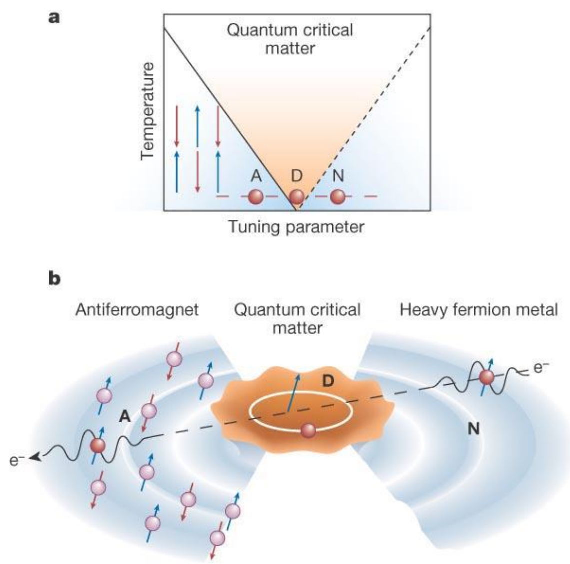
Quantum Criticality of Magneto-Electric Materials

Quantum criticality refers to a set of intriguing universal phenomena observed at finite temperatures, which counter-intuitively stems from a zero-temperature phase transition. We learned in classroom that phase transitions occur as temperature is changed, for instance, a magnetic order is lost as we heat up the magnet. On the other hand, phase transition can occur at absolute zero by applying a pressure or magnetic field. Such transitions are driven not by thermal fluctuations (they do not exist at absolute zero!) but quantum fluctuations, hence called quantum phase transitions. This paves a path in the phase diagram where strong quantum fluctuations can survive up to rather high temperatures, giving rise to exotic phases or critical behaviour. Yet our understanding of quantum criticality is only at its beginning.



The aim of this project is to quantify quantum criticality of magneto-electric materials where two degrees of freedom, magnetic and electric dipoles, are coupled. The main question would be, though challenging, whether the fluctuations of these two quantities are separable or intertwined in quantum critical region. As a first step, the student will build and activate a dielectric property measurement system, and by using it to characterise model magneto-electric materials at cryogenic temperatures. As a second step, the student will explore the material's dielectric response in a wide range of temperature and a magnetic field, e.g., down to 1.5 kelvin and up to 18 tesla, or even in a three-dimensional vector magnetic field. In particular, careful measurements and analysis will be performed in parallel in a quantum critical region. The project will include typical training for hands-on laboratory works for quantum materials and solid-state physics research, which comprises low-temperature thermometry and electric wiring and measurements, instrument programming, data and numerical analysis, technical writing and handling of cryogenic liquid.

Depending on the student's interest, the contents and approach of the project is adjustable. This project is a part of our group's research activities.

For those interested, feel free to contact Prof. Henrik M. Ronnow (henrik.ronnow@epfl.ch) for further information and discussion.

Reference: P. Coleman and A. Schofield, Nature, **433**, 226 (2005) (access allowed at EPFL)