The theory of surface quantum criticality

Solid state physics is full of surprises. For example mathematical description of crystalline metals completely disregarding inter-electron electrostatic interactions (so-called Drude model) gives qualitatively correct predictions for many of their properties. Formulated before the World War II, the Sommerfeld model, being in fact a Drude model with corrections stemming from developed meanwhile quantum theory (and still ignoring the electrostatic electron-electron interactions), is so efficient for description of metals that happens to be used to this day. These surprisingly good results of such simple models are partly explained by the fact that in metals electric charges move easily, and in practice the charge of a given electron is screened by the other electrons.

The Drude-Sommerfeld model explained a lot of features of conventional metals. However, not all the materials can be modeled so easily. A particular examples are the layered compounds containing rare-earth atoms. In their case, a description taking into account electron interactions is necessary. Current theories usually achieve this by approximate computation scheme called *dynamical mean field theory* (DMFT). It allows for material-specific calculations of material properties, and a qualitative understanding within simplified models.

One of the lessons from DMFT and experimental investigations is that materials tend to have the most extraordinary properties at the transition point between two more conventional phases. When the transition is caused by a non-thermal trigger, such as magnetic field or change of the chemical composition, it is called a *quantum phase transition*, for the prominent role of quantum fluctuations. Many of the high-temperature superconductors are examples of phases stabilized by the vicinity of such quantum phase transitions, or shortly by *quantum criticality*.

An important difficulty for DMFT models is posed by irregularities in the materials. An example of significant irregularity is existence of the material surface: atoms there have obviously a different surrounding than these in the bulk. Understanding of the phenomena taking place at the surface of the material requires additional efforts. Recent experiments performed on strontium ruthenate samples with scanning tunneling microscope have shown that their surface behaves completely differently than the bulk. At circumstances where the bulk is a conventional metal, the surface is magnetically ordered, anisotropic, and resembles the bulk at *quantum criticality* caused by strong magnetic field. This suggests that quantum criticality of the surface can be sometimes realized easier than in the bulk, opening a new avenue for designing new materials of previously inaccessible properties.

In the present project it is proposed to develop a DMFT theory of a surface of interacting layered material, test it against the experimental results concerning the strontium ruthenate, and use to predict the complete phase diagram of this material surface. Such a theory will also allow to better interpret the existing experimental results and may guide further advances in material design. It will be applicable to many other materials.