Offered 'Master Thesis Project' at the Low Temperature Physics Laboratory

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Title of the project: *Scanning tunneling microscopy at extreme magnetic fields*

Abstract:

A major challenge for condensed matter physics are systems with strong electron-electron interactions. Along with pressure and temperature, the magnetic field is one of the physical parameters that are used for the investigation of electronic properties in metals, semiconductors, and superconductors. Electrons interact with a magnetic field through the magnetic moment caused by spin- and orbital-angular momenta, or cyclotron motion caused by the Lorentz force. The interaction energy of matter with a magnetic field, i.e. Zeeman energy or Landau energy increases strongly with increasing field providing an important tool for investigating the electronic properties.

So far, techniques used to sense electronic correlations under strong magnetic fields are macroscopic and provide spatially averaged information. Scanning tunneling microscopes (STM) operated at low temperatures can readily resolve spatial variation of electronic properties with sub-meV resolution and down to the atomic scale. But today the magnetic fields accessible for state of the art STM imaging are well below those used in macroscopic measurements. Microscopes with high magnetic fields will allow the direct visualisation of the electronic correlations, necessary to give conclusive answers to questions in fields such as graphene, nanotechnology, superconductivity or magnetism.

In this project, we will use a STM at very high magnetic fields in ultra-low vibration premises recently built at UAM using available superconducting magnets up to 22 T (see https://www.oxinst.com/news/oxford-instruments-commissions-22-tesla-superconducting-magnet-system) to study electronic correlations in a model compound, $CeRu_2Si_2$. This system has been studied in great detail using macroscopic techniques and shows a quantum critical point when making small changes of Ru by Rh. At the quantum critical point, spatial and temporal length scales for quantum fluctuations diverge and radically modify the behaviour of the whole sample. The usual fermionic description of electronic excitations breaks down, leading to a new quantum entangled state which we propose to study in detail here using STM.