Highlights

Electronic and thermal transport from the nanoscale to the macroscale - 2018

Fluctuation spectroscopy: From Rayleigh-Jeanswaves to Abrikosov vortex clusters

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Superconducting (SC) fluctuations, discovered in the late 1960s, have constituted an important research area in superconductivity as they are manifest in a variety of phenomena. Indeed, the underlying physics of SC fluctuations makes it possible to elucidate the fundamental properties of the superconducting state. The interest in SC fluctuation phenomena was further enhanced with the discovery of cuprate high-temperature superconductors (HTSs). In these materials, superconducting fluctuations appear over a wide range of temperatures due to the superconductors extremely short coherence lengths and low effective dimensionality of the electron systems. These strong fluctuations lead to anomalous properties of the normal state in some HTS materials. Within the framework of the phenomenological Ginzburg-Landau theory, and more extensively in the diagrammatic microscopic approach based on BCS theory, SC fluctuations as well as other quantum contributions (weak localization, etc.) enabled a new way to investigate and characterize disordered electron systems, granular metals, Josephson structures, artificial superlattices, and others. The characteristic feature of SC fluctuations is its strong dependence on temperature and magnetic field in the vicinity of the superconducting phase transition. This dependence allows the separation of fluctuation effects from other contributions and provides information about the microscopic parameters of a material, in particular, the critical temperature and the zero-temperature critical magnetic field. As such, SC fluctuations are very sensitive to the relaxation processes that break phase coherence and can be used as a versatile characterization instrument for SCs: Fluctuation spectroscopy has emerged as a powerful tool for studying the properties of superconducting systems on a quantitative level. Here the physics of SC fluctuations is reviewed, commencing from a qualitative description of thermodynamic fluctuations close to the critical temperature and quantum fluctuations at zero temperature in the vicinity of the second critical field. The analysis of the latter allows us to present fluctuation formation as a fragmentation of the Abrikosov lattice. This review highlights a series of experimental findings followed by microscopic description and numerical analysis of the effects of fluctuations on numerous properties of superconductors in the entire phase diagram and beyond the superconducting phase.

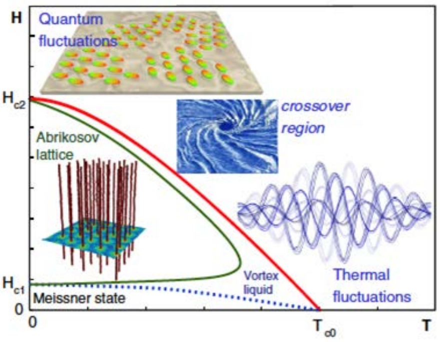

Fig. 1: Schematic phase diagram of type-II superconductors, showing the domains of qualitatively different physical behavior.

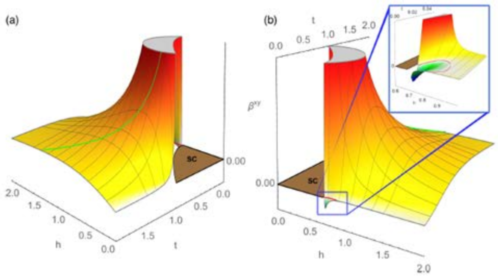

Fig. 2: The magnetic field and temperature dependence of the fluctuation part of the Nernst coefficient. (a) A view from the *h*=0 plane with the ghost field line in green (light gray) indicating the maximum of the Nernst coefficient for constant. (b) A view from the *t*=0 plane with a zoom close to the quantum fluctuation region at h=h_{c2}. The red (dark gray) line indicates the contour where the Nernst coefficient becomes zero.