Spatial Correlations in the Vortex Matter Systems

The study of vortices in superconductors, so-called vortex matter physics, has made important contributions to aspects of statistical physics, classical correlations, order-disorder transitions and related phenomena, and has connections to other fields such as polymer and colloidal physics. In the cuprate superconductors the combination of high superconducting anisotropy, extreme type-II materials parameters (high λ and low ξ) and high temperatures gives rise to a whole zoo of exotic vortex phases including vortex solids, vortex liquids and vortex glasses [1]. Many years ago we used the μSR technique [2] combined with small-angle neutron scattering [3] to probe local variations in the order associated with vortex lattice melting and also with a disorder-induced transition to a vortex glass (VG) phase. Similar behaviour was also later observed in the highly anisotropic superconducting organic BEDT charge transfer salts [4].

In recent years I have revisited this topic following the realisation that higher moments of the field distributions derived from μSR experiments gives information on higher order spatial correlations of the disordered vortex system [5]. In disordered systems scattering experiments reveal the structure factor $S(q)$, related to pair-pair density correlations, but do not contain information on three body correlations. From this perspective the vortex system becomes an interesting system in which to study classical correlations, where three-body correlations are in general not easily accessible in the bulk of system, although studies on colloids provide information at surfaces *via* real space observations. The initial experiments were carried out the cuprate LSCO, chosen as an archetypical example of a system of high but not extreme superconducting anisotropy. Here we showed that the vortex glass (VG) phase could be shown to exhibit non-trivial three-body correlations that, under certain conditions of two-body disorder, give a unique signature of a negative third moment of the field distribution [5].

We have recently extended this analysis to a comprehensive study of the phase diagram of the highly anisotropic cuprate BSCCO, and also BSCCO subject to irradiated with heavy ions to produce randomly distributed defects intended to disrupt spatial correlations. Earlier studies on irradiated samples had focussed only on two-body correlations [6,7], but here we make a complete survey of quantities related two both two-body and three-body correlations in both the pristine and irradiated materials. These results show some unexpected surprises, including changes in glassy order within the VG phase of the pristine material.

In the talk I will present a brief background to the topic of vortex matter, followed by a discussion of largely unpublished new results on the local correlations of the vortex system in disordered phases as a function of field and temperature.

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