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Crossover from Three – to Two-Dimensional Behavior of the Vortex Energies in Layered XY-Models for High T_c Superconductors

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Abstract

We use Monte Carlo simulations of a layered XY-model to study the phase fluctuations in high T_c superconductors. A vortex-antivortex interaction dominated by a term linear in the vortex separation is found in the low temperature regime. This is in agreement with a zero temperature variational calculation. At temperature just above the 2D vortex unbinding temperature the linear term vanishes and an ordinary 2D vortex behaviour is found. This explains the finding that the High T_c superconductors show 2D properties in the vortex fluctuations responsible for the resistivity transition close to the critical temperature.

Results

$$E(a) = E_c + E_1 \ln(\frac{a}{a_0}) + E_2(\frac{a}{a_0} - 1)$$

Our main result is that vortex fluctuations in the adjacent plane makes the coefficient of the linear term in the energy vanish as the temperature increases. As this happens the vortex-antivortex interaction recovers its usual two dimensional logarithmic form. This happens for temperatures just above the vortex unbinding temperature of the two dimensional XY model. This finding might explain how the layered three dimensional high temperature superconductors can exhibit two dimensional Coulomb gas scaling behavior in the the resistivity transition.

References

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