Unconventional Magnetic Phase Diagram of Cuprate Superconductor $La_{2-x}Sr_xCuO_4$ at Quantum Critical Point x = 1/9

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We have studied field-cooled magnetization of La1.89Sr0.11CuO4 as a function of temperature and magnetic fields. 2D critical fittings [1], [2] to the entire reversible field-cooled magnetization revealed a new phase boundary $T_{m2}(H)$ that buries deeply below the first order vortex melting line in the vortex solid phase. We observed a field-induced enhancement of antiferromagnetism (AF) which can be attributed to the proximity to a quantum critical point (QCP) where superconductivity and spin density wave (SDW) coexist microscopically, the SC+CDW phase. In the SC+CDW phase the correction to the lowest magnetic energy mode is $\sim |\nu|[H/(2H_{c2}) \times ln(\theta H_{c2}/H)]$ where ν is the coupling constant between SC and SDW [3]. We find that the coupling constant ν is negative below $T_{m2}(H)$ while positive above. We conclude that the microscopically coexisting antiferromagnetism collaborates with the high temperature superconductivity in cuprates below $T_{m2}(H)$. We present a new unconventional magnetic phase diagram of $La_{2-x}Sr_xCuO_4$ around quantum critical point x = 1/9.

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