Induced Magnetic Moment in the Magnetic Catalysis of Chiral Symmetry Breaking

Efrain J. Ferrer

Department of Physics, The University of Texas at El Paso, USA

Introduction

The chiral symmetry breaking in an NJL-type effective model of quarks in the presence of a magnetic field is investigated. We show that new interaction tensor channels open up via Fierz identities due to the explicit breaking of the rotational symmetry by the magnetic field. We demonstrate that the magnetic catalysis of chiral symmetry breaking leads to the generation of two independent condensates, the conventional chiral condensate and a spin-one condensate. While the chiral condensate generates, as usual, a dynamical fermion mass, the new condensate enters as a dynamical anomalous magnetic moment in the dispersion of the quasiparticles. An external magnetic field can align the pairs' magnetic moments giving rise to a net magnetic moment for the ground state. Our results show that the magnetically catalyzed ground state in QCD is actually richer than previously thought. The two condensates contribute to the effective mass of the lowest Landau level quasiparticles in such a way that the critical temperature for chiral symmetry restoration becomes enhanced.

Magnetic Moment of Chiral Pairs

$$\mathcal{L} = \bar{\psi} i\gamma^{\mu} D_{\mu}\psi + \mathcal{L}_{int}^{(1)} + \mathcal{L}_{int}^{(2)}$$

$$\mathcal{L}_{int}^{(1)} = \frac{G}{2}[(\bar{\psi}\psi)^2 + (\bar{\psi}i\gamma^5\psi)^2],$$

$$\mathcal{L}_{int}^{(2)} = \frac{G'}{2}[(\bar{\psi}\Sigma^3\psi)^2 + (\bar{\psi}i\gamma^5\Sigma^3\psi)^2],$$

$$\eta_{\parallel}^{\mu\nu} = \eta^{\mu\nu} - \widehat{F}^{\mu\rho}\widehat{F}_{\rho}^{\nu}, \quad \eta_{\perp}^{\mu\nu} = \widehat{F}^{\mu\rho}\widehat{F}_{\rho}^{\nu}$$

$$\widehat{F}_{\mu\nu} = F_{\mu\nu}/|B|$$

$$\gamma^{\parallel} = \eta_{\parallel}^{\mu\nu}\gamma_{\nu}, \quad \gamma^{\perp} = \eta_{\perp}^{\mu\nu}\gamma_{\nu}$$

$$\mathcal{L}_{int} = \frac{g_{\parallel}^2}{2\Lambda^2}(\bar{\psi}\gamma_{\parallel}^{\mu}\psi)(\bar{\psi}\gamma_{\mu}^{\parallel}\psi) + \frac{g_{\perp}^2}{2\Lambda^2}(\bar{\psi}\gamma_{\perp}^{\mu}\psi)(\bar{\psi}\gamma_{\mu}^{\perp}\psi).$$

$$G = (g_{\parallel}^2 + g_{\perp}^2)/2\Lambda^2, \qquad G' = (g_{\parallel}^2 - g_{\perp}^2)/2\Lambda^2$$

Condensates

$$\langle\bar{\psi}\psi\rangle = -\frac{\sigma}{G}, \qquad \langle\bar{\psi}i\gamma^5\psi\rangle = -\frac{\Pi}{G},$$

$$\langle\bar{\psi}i\gamma^1\gamma^2\psi\rangle = -\frac{\xi}{G'}, \qquad \langle\bar{\psi}i\gamma^0\gamma^3\psi\rangle = -\frac{\xi'}{G'},$$

Condensates' Solutions

Gap Equation

$$\int_0^{\Lambda} \frac{dp_3}{\sqrt{p_3^2 + (1+\frac{G'}{G})^2(\overline{\sigma}^2 + \overline{\Pi}^2)}} = \frac{4\pi^2}{(G+G')N_c qB}$$

Condensates' Solutions

$$\overline{\sigma} = \left(\frac{2G\Lambda}{G+G'}\right)\exp - \left[\frac{2\pi^2}{(G+G')N_c qB}\right]$$

$$\overline{\xi} = \left(\frac{2G'\Lambda}{G+G'}\right)\exp - \left[\frac{2\pi^2}{(G+G')N_c qB}\right]$$

Dynamical Mass and Critical Temperature

$$M_{\xi} = \overline{\sigma} + \overline{\xi} = 2\Lambda\exp - \left[\frac{2\pi^2}{(G+G')N_c qB}\right]$$

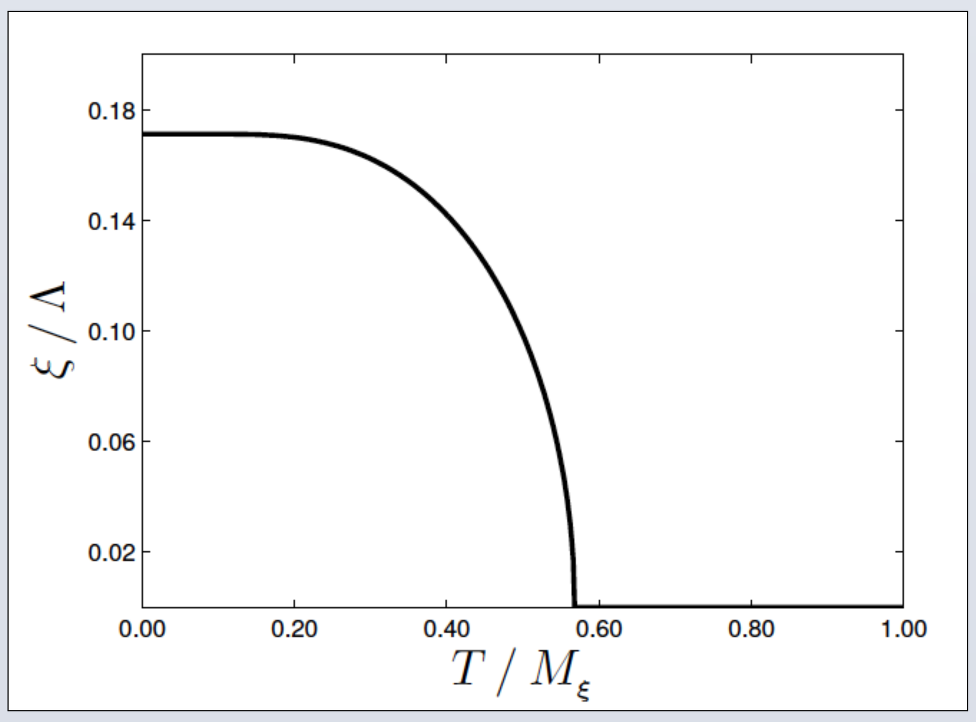
$$G' = \eta G \qquad qB/\Lambda^2 \sim 1,\ \eta \simeq 1$$

$$G\Lambda^2 = 1.835,$$

$$\ln\left(\frac{M_{\xi}}{M_{\xi=0}}\right) = 1.8$$

Critical Temperature

$$T_{C_{\chi}} = 1.6\Lambda\exp - \left[\frac{2\pi^2}{(G+G')N_c qB}\right] = 0.8M_{\xi}$$



References

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