Inverse magnetic catalysis in QCD

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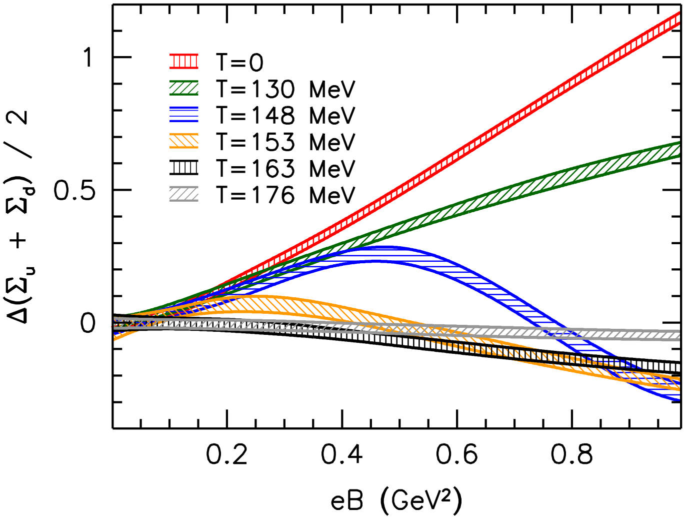
July 31, 2013

Is there always magnetic catalysis?

- Common wisdom:
  chiral condensate increases with the magnetic field
  - Low energy effective models
  - First lattice study: D'Elia et al., 2010
- But! Bali et al., 2012 : around T_c condensate can decrease
  - Physical quark masses
  - Continuum limit

Dependence of the condensate on the magnetic field

Bali et al. PRD (2012)



What happens if B is switched on?

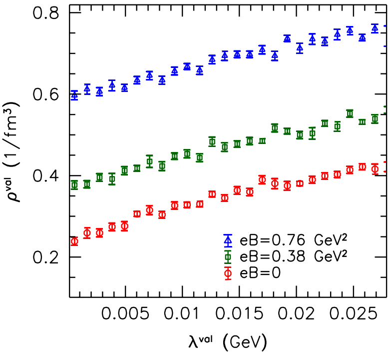
- Quark condensate:

$$\langle\bar\psi\psi\rangle(B) = \frac{1}{Z}\int dA\, e^{-S(A)} \underbrace{\det[D(A,B)+m]}_{\text{“sea”}} \underbrace{\mathrm{Tr}\left[(D(A,B)+m)^{-1}\right]}_{\text{“valence”}}$$

- Why does the condensate depend on B?
  - Spectrum of $D(A,B)$ in given gauge backgound changes $\rightarrow$ “valence”
  - Typical gauge field A changes $\rightarrow$ “sea”

Change of Dirac spectral density with B

$T = 142$ MeV, $N_t = 6$, generated with $B = 0$



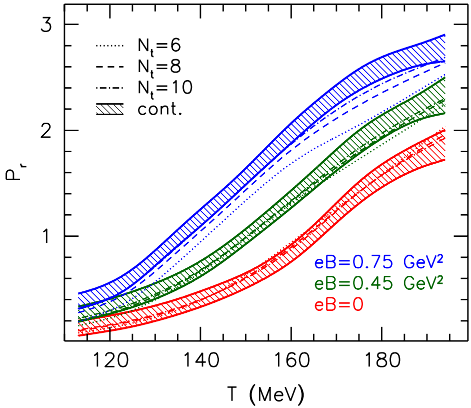
- $\rightarrow$ spectral density around zero increases with B
- $\rightarrow$ $\langle\bar{\psi}\psi\rangle$ increases
- $\rightarrow$ magnetic catalysis

How does B influence the gauge fields?

- What happens to the gauge field if B is switched on?

How does B influence the gauge fields?

- What happens to the gauge field if B is switched on?
- Polyakov loop increases (gets more ordered)



Why does the Polyakov loop increase with B?

- Quark action:

$$S_q = -\log\det(D+m) = -\sum \log(\lambda_i + m)$$

- m small
  $\rightarrow$ fluctuations of S_q dominated by small eigenvalues

- Quark action suppresses small Dirac eigenvalues

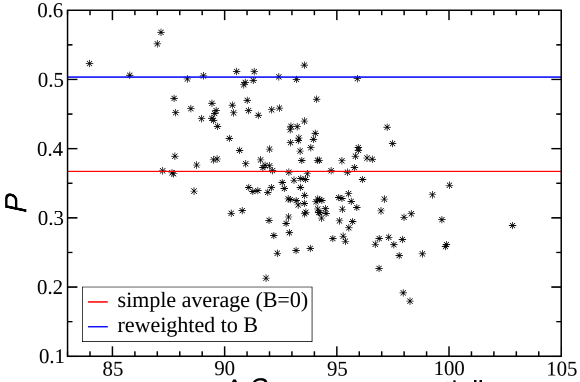
- Few small eigenvalues $\Leftrightarrow$ large Polyakov loop
  - $T \ll T_c \rightarrow P \approx 0 \rightarrow$ many small modes (sχSB)
  - $T \gg T_c \rightarrow P \approx 1 \rightarrow \lambda_1 \propto T$ (lowest Matsubara mode)

- Quark action prefers large Polyakov loop;
  switching on B enhances this effect

Change in action versus the Polyakov loop

Scatter plot of $10^3 \times 4$ lattice configurations around T_c, generated with $B = 0$

$$\Delta S_q = \log\det(D(0, A) + m) - \log\det(D(B, A) + m)$$



$\Delta S_q \quad \rightarrow$ exponentially suppressed by B

The Polyakov loop and the condensate

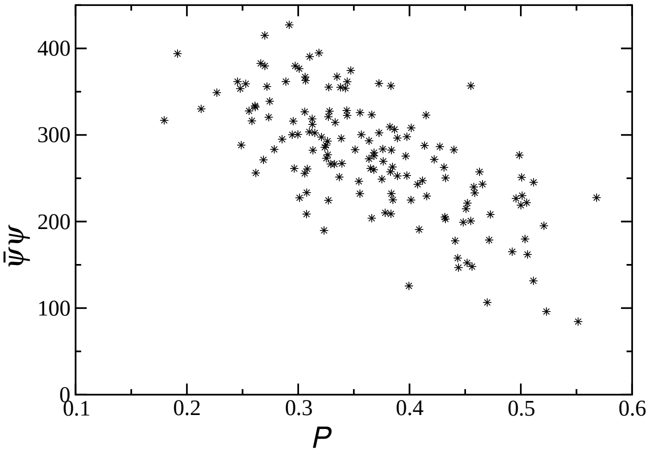
- Condensate:

$$\bar{\psi}\psi \approx \sum \frac{1}{\lambda_i + m}$$

- m small $\rightarrow$ dominated by small eigenvalues
- P large $\rightarrow$ fewer small eigenvalues
- $\rightarrow$ smaller condensate

Polyakov loop versus quark condensate

Scatter plot of $10^3 \times 4$ lattice configurations around T_c



Competition between “sea” and “valence”

- Magnetic field $\rightarrow$ more small Dirac eigenvalues
- Valence
  - More small modes $\rightarrow$ larger condensate
- Sea
  - suppresses configurations with many small modes
  - suppression enhanced by magnetic field
  - quark condensate decreases
- “Sea” and “valence” compete

Why does the "sea" win at T_c?

- T_c cross-over — order parameter Polyakov loop
- At T_c Polyakov loop effective potential flat
- Small magnetic field contribution has large ordering effect

Conclusions

- Both catalysis and inverse catalysis depend on small quark modes
- Inverse catalysis: suppression of small Dirac ev's by B in the quark det
- Contribution of B in det to the P-loop effective potential becomes important at T_c
- Small modes $\rightarrow$ sensitive to quark mass