Inverse Magnetic Catalysis in Holographic Models of QCD

based on
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2. Hawking-Page or confinement/deconfinement transition in hard-wall AdS/QCD
   - for $B = 0$
   - for $B \neq 0$

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5. Summary and conclusion

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$$T_c = T(r_h = r_{hc}) = \frac{2^{1/4}}{\pi} r_0 = T_{dec}$$

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where the on-shell Euclidean bulk action $S^{\rm E}_{\rm bulk}$ is

$$S^{\rm E}_{\rm bulk} = \frac{V_3}{8\pi G_5} \int_0^{\beta} dt_E \int_{r'}^{r_\Lambda} dr \sqrt{g} \left(4 + \frac{2}{3} B^2 g^{xx} g^{yy} \right) ,$$

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$$S^{\rm E}_{\rm bndy} = -\frac{V_3}{8\pi G_5}\int_0^\beta dt_E \sqrt{\gamma}\left(K - 3 + B^2 g^{xx} g^{yy} \ln r_\Lambda\right)$$

Hawking-Page or confinement/deconfinement transition in hard-wall AdS/QCD for $B \neq 0$

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- AdS_5 black hole [D'Hoker and Kraus (2009)]

$$ds^2_{\mathrm{bh}} = r^2\left(f(r)dt_E^2 + q(r)dz^2 + h(r)\left(dx^2+dy^2\right)\right) + \frac{dr^2}{f(r)r^2}\,,$$

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h(r) &= 1 + \frac{1}{3}B^2\frac{\ln r}{r^4} + \mathcal{O}(B^4)\ ,\\
T &= \frac{1}{\beta} = \frac{r_h}{2\pi}\left(1 + \frac{M}{r_h^4} - \frac{2}{3}B^2\left(\frac{1}{2r_h^4} - \frac{\ln r_h}{r_h^4}\right)\right) + \mathcal{O}(B^4)
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- the free energy of the AdS_5 black hole

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\end{aligned}
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- the free energy of the AdS_5 black hole

$$
F_{\rm bh} = -\frac{V_3}{8\pi G_5}\left(r_h^4 - \frac{1}{2}M + \frac{2}{3}B^2\ln r_h - \frac{1}{3}B^2\right) + \mathcal{O}(B^4)
$$

Hawking-Page or confinement/deconfinement transition in hard-wall AdS/QCD for $B \neq 0$

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- thermal-AdS_5

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$$
\begin{aligned}
ds^2_{\rm thermal} &= r^2\left(f_0(r)dt_E^2 + q(r)dz^2 + h(r)\left(dx^2+dy^2\right)\right) + \frac{dr^2}{f_0(r)r^2}\ , \\
f_0(r) &= 1 - \frac{2}{3}B^2\frac{\ln r}{r^4} + \mathcal{O}(B^4)\ , \\
q(r) &= 1 - \frac{2}{3}B^2\frac{\ln r}{r^4} + \mathcal{O}(B^4)\ , \\
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T &= \frac{1}{\beta}
\end{aligned}
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- the free energy of the thermal-AdS_5

$$
F_{\text{th}} = -\frac{V_3}{8\pi G_5}\left(r_0^4 + \frac{2}{3}B^2\ln r_0 - \frac{1}{3}B^2\right) + \mathcal{O}(B^4)
$$

Hawking-Page or confinement/deconfinement transition in hard-wall AdS/QCD for $B \neq 0$

Hawking-Page or confinement/deconfinement transition in hard-wall AdS/QCD for $B \neq 0$

- the difference between the free energies

Hawking-Page or confinement/deconfinement transition in hard-wall AdS/QCD for $B \neq 0$

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$$\Delta F = -\frac{V_3}{8\pi G_5}\left(r_h^4 - r_0^4 - \frac{1}{2}M + \frac{2}{3}B^2\ln(\frac{r_h}{r_0})\right) + \mathcal{O}(B^4)$$

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- the critical temperature for the Hawking-Page or confinement/deconfinement transition

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$$\Delta F(r_h = r_{hc}) = -\frac{V_3}{8\pi G_5}\left(r_{hc}^4 - r_0^4 - \frac{1}{2}M + \frac{2}{3}B^2 \ln(\frac{r_{hc}}{r_0})\right) + \mathcal{O}(B^4) = 0\,,$$

Hawking-Page or confinement/deconfinement transition in hard-wall AdS/QCD for $B \neq 0$

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$$r_{hc}^4 + \frac{2}{3}B^2\ln(\frac{r_{hc}}{r_0}) - 2r_0^4 + \mathcal{O}(B^4) = 0,$$

Hawking-Page or confinement/deconfinement transition in hard-wall AdS/QCD for $B \neq 0$

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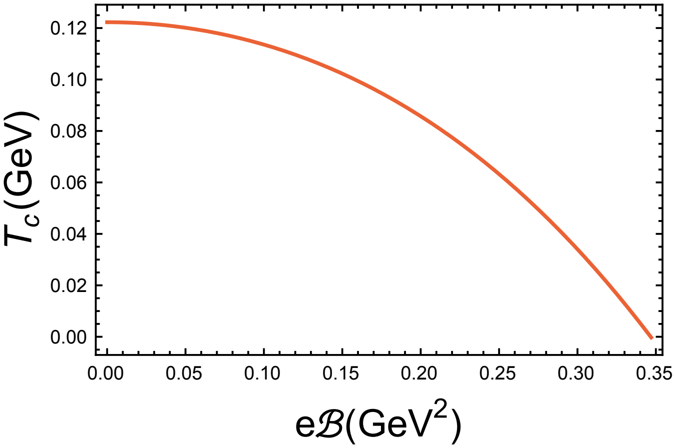
$$r_{hc}^4 + \frac{2}{3}B^2 \ln(\frac{r_{hc}}{r_0}) - 2r_0^4 + \mathcal{O}(B^4) = 0,$$

$$T_c = T(r_h = r_{hc}) = T_{dec}$$


0.12
0.10
0.08
0.06
0.04
0.02
0.00
T_c(GeV)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
$e\mathcal{B}(\text{GeV}^2)$

$\mathcal{N} = 4$ SYM on $S^1_\beta \times R^2 \times S^1_\ell$

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- the gluons do not acquire masses

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- scalars obey periodic boundary conditions around the circle S^1_ℓ, hence they are massless at tree-level and acquire masses only at the quantum level through their couplings to the fermions
- the gluons do not acquire masses
- therefore, at low-energy, $\mathcal{N} = 4$ SYM on $S^1_\beta \times R^2 \times S^1_\ell$ reduce to pure 3D Yang-Mills theory

Hawking-Page or confinement/deconfinement transition in $\mathcal{N} = 4$ SYM on $S^1_\beta \times R^2 \times S^1_\ell$ for $B = 0$

Hawking-Page or confinement/deconfinement transition in $\mathcal{N} = 4$ SYM on $S^1_\beta \times R^2 \times S^1_\ell$ for $B = 0$

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f_s(r) &= 1 - \frac{r_0^4}{r^4} \ ,
\end{aligned}
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$$\Delta F \;=\; F_{\mathrm{bh}} - F_{\mathrm{soliton}} = -\frac{V_3}{8\pi G_5}\left(\frac{r_h^4}{2} - \frac{r_0^4}{2}\right)$$

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$$\Delta F(r_h = r_{hc}) = -\frac{V_3}{8\pi G_5}\left(\frac{r_{hc}^4}{2} - \frac{r_0^4}{2}\right) = 0\,,$$

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$$
\begin{aligned}
ds^2_{\text{soliton}} &= r^2\left(f_s(r)dz'^2 - q(r)dt'^2 + h(r)\left(dx^2 + dy^2\right)\right) + \frac{dr^2}{f_s(r)r^2}\ , \\
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h(r) &= 1 + \frac{1}{3}B^2\frac{\ln r}{r^4} + \mathcal{O}(B^4)\ , \\
\frac{1}{\ell} &= \frac{r_0}{2\pi}\left(1 + \frac{M}{r_0^4} + \frac{2}{3}B^2\left(\frac{\ln r_0}{r_0^4} - \frac{1}{2r_0^4}\right)\right) + \mathcal{O}(B^4). \\
T &= \frac{1}{\beta}
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- Hawking-Page transition is between AdS_5 black hole and AdS_5-soliton geometries, now including the backreaction of the D7 branes

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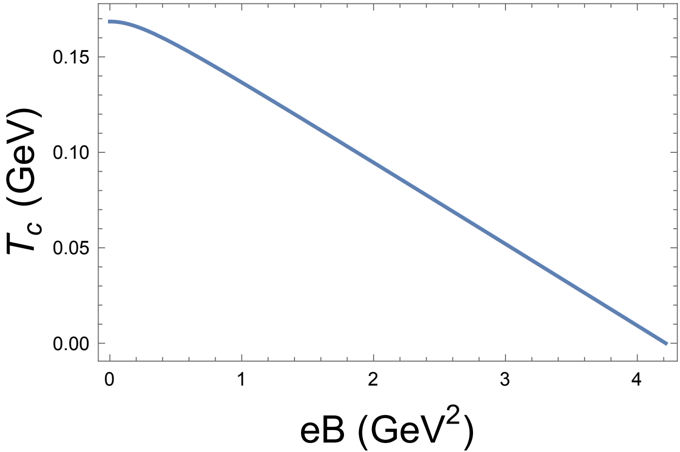
0.15
0.10
0.05
0.00
0
1
2
3
4
T_c (GeV)
eB (GeV^2)

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Thank You!