Quarkonium Dissociation in a Thermal Medium

Jakub Jankowski & D.B., “Heavy-Quark Physics”, DESY-PROC-2009-07; [hep-ph/0903.1263]

$$V_{\rm sc}(q) = V(q)/[1 + F(0;\mathbf{q})/q^2]\ , \qquad V(q) = -\tfrac{4}{3}g^2/q^2,\ q^2 = |\mathbf{q}|^2$$

Gluon polarisation function: $F(0;\mathbf{q}) = -\Pi_{00}(0;\mathbf{q})$

$$\Pi_{00}(i\omega_l;\mathbf{q}) = Tg^2 \sum_{n=-\infty}^{\infty} \int \frac{d^3p}{(2\pi)^3}\, {\rm Tr}[\gamma^0 S_\Phi(i\omega_n;\mathbf{p})\gamma^0 S_\Phi(i\omega_n - i\omega_l;\mathbf{p}-\mathbf{q})]\ ,$$

Matsubara frequencies: $\omega_l = 2\pi l T \qquad \omega_n = (2n+1)\pi T$

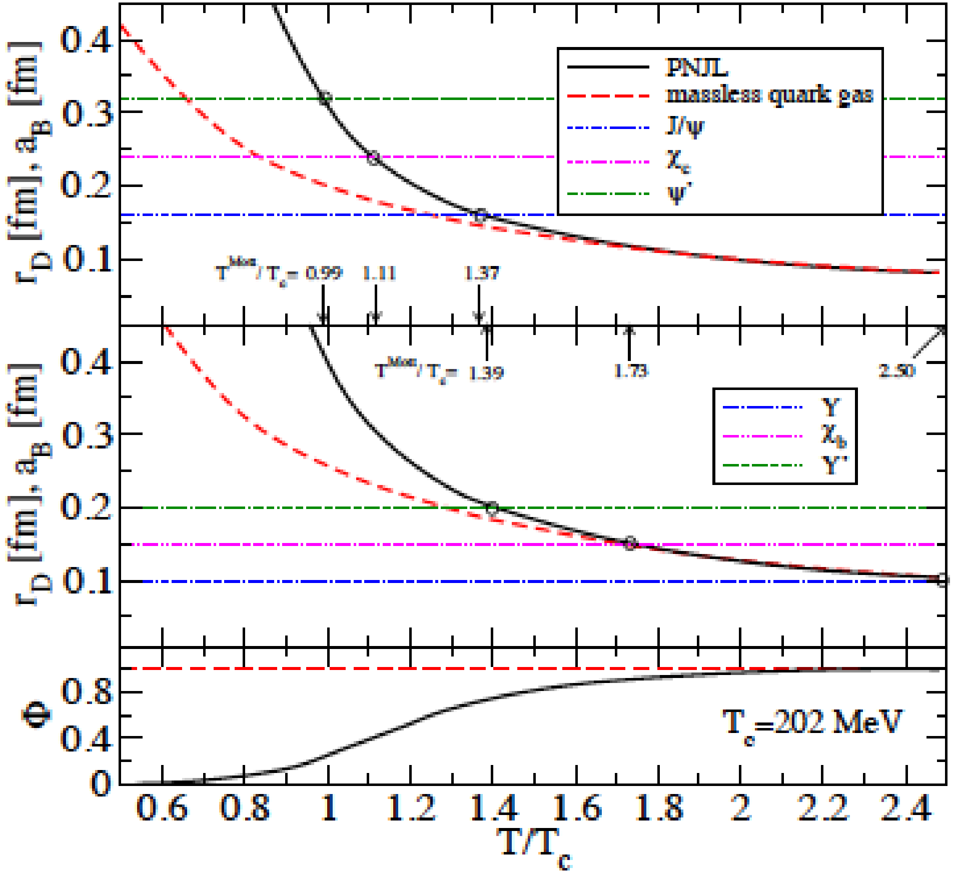
Quark propagator in Polyakov Loop: $S_\Phi^{-1}(\mathbf{p};\omega_n) = \gamma\cdot\mathbf{p} + \gamma_0 i\omega_n - \lambda_3\varphi_3\ ,$

$$\Phi(T) = \frac{1}{3}{\rm Tr_c}(e^{i\beta\lambda_3\varphi_3}) = \frac{1}{3}(1 + 2\cos(\beta\varphi_3))\ .$$

$$\Pi_{00}(0;\mathbf{q}) = \frac{2N_{\rm dof}g^2}{\pi^2}\int_0^\infty dp\, p^2 \frac{\partial f_\Phi}{\partial p} = -\frac{4N_{\rm dof}g^2}{\pi^2}\int_0^\infty dp\, p\, f_\Phi(p)$$
$$= -\frac{N_{\rm dof}g^2T^2}{3} I(\Phi) = -m_D^2(T)\ .$$

$$I(\Phi) = \frac{12}{\pi^2}\int_0^\infty dx\, x \frac{\Phi(1+2e^{-x})e^{-x} + e^{-3x}}{1 + 3\Phi(1+e^{-x})e^{-x} + e^{-3x}}\ .$$

Screened potential in a PL quark plasma: $V_{\rm sc}(q) = -4\pi\alpha/[q^2 + m_D^2(T)]$



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$$H = -\frac{\nabla^2}{m_Q} - \frac{\alpha}{r} e^{-m_D(T) r} ,$$

Trial wave function: $\psi_{1S}(r;\gamma) = \sqrt{\frac{\gamma^3}{\pi}} \exp(-\gamma r)$

$$E_{1S}(\gamma, T) = \langle \psi_{1S}(\gamma) \mid H \mid \psi_{1S}(\gamma) \rangle = \frac{\gamma^2}{m_Q} - \frac{4\alpha\gamma^3}{(m_D(T) + 2\gamma)^2} .$$

Ritz variational principle: $dE_{1S}(\gamma, T)/d\gamma = 0$

Mott dissociation condition: $E_{1S}(\gamma, T^{\mathrm{Mott}}) = 0$

$r_D(T_{1S}^{\mathrm{Mott}}) = a_0$, $a_0 = 2/(\alpha m_Q) = 1/\sqrt{\varepsilon_0 m_Q}$ (Bohr radius)

$$T^{\mathrm{Mott}} = \sqrt{3\varepsilon_0 m_Q / N_{\mathrm{dof}}} / g = \sqrt{\sqrt{\varepsilon_0 m_Q^3} / (2\pi N_{\mathrm{dof}})} .$$

$$T^{\mathrm{Mott},\Phi} = T^{\mathrm{Mott}} / \sqrt{I(\Phi)} .$$

Table 1: Mott temperatures T^{Mott} ($T^{\mathrm{Mott},\Phi}$) according to Eq. (11) (Eq. (12)) for a massless ideal quark gas (PNJL model). The critical temperature is $T_c = 202$ MeV [13]. The parameters are fixed to reproduce quarkonium states in vacuum as Coulombic bound states [14]. In the charmonium (bottomonium) system the heavy quark mass m_Q is $m_c = 1.94$ GeV ($m_b = 5.1$ GeV) and the ground state binding energy ε_0 is 0.78 GeV (0.75 GeV).

	T^{Mott}/T_c	$T^{\mathrm{Mott},\Phi}/T_c$
J/ψ	1.25	1.37
χ_c	0.83	1.11
ψ'	0.66	0.99
Υ	2.50	2.50
χ_b	1.72	1.73
Υ'	1.28	1.39