Dynamical gluon mass at nonzero temperature in the instanton vacuum model

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Outline

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- Gluons at non-zero temperature
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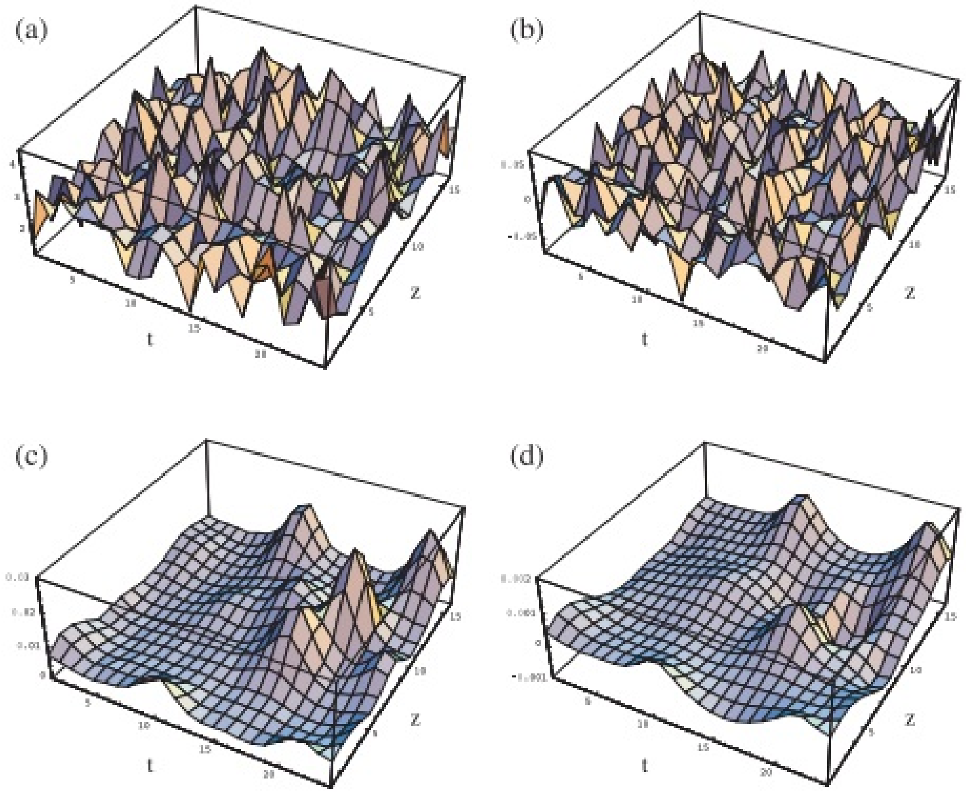
Introduction

- The properties of QCD vacuum are important. We consider them in the instanton liquid model(ILM) at non-zero temperature for the mean instanton size $\rho(T)$ and density $n(T)$
- Gluon propagator gives a contribution to the one-gluon exchange perturbative $Q\bar{Q}$ potential
- Temperature dependencies of dynamical gluon mass in ILM

QCD vacuum at zero temperature

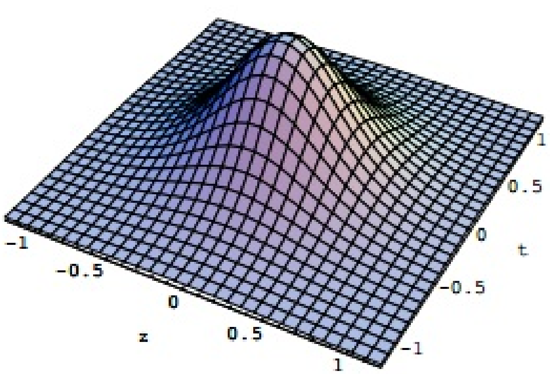
- The vacuum(=the ground state) is made of zero-point ossilations of the fields $A_i(x,t)$ on top of classical field configurations $A^{class}(x,t)$

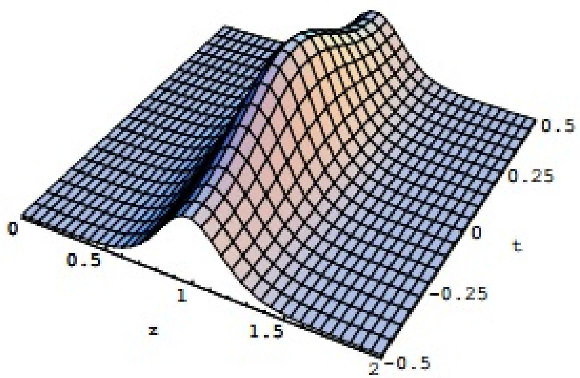


- up: action density, before and after smearing
- down: so-called topological charge density

- Computer simulations of the Yang-Mills vacuum [L.Negele et al.]

- Instanton as a large fluctuation of the gluon field in imaginary time corresponding to quantum tunneling from one of minimum of the potential energy to the neighbor one
- Generalization of standart instanton to $T \neq 0$: periodic instanton of Harrington and Shepard(1978)

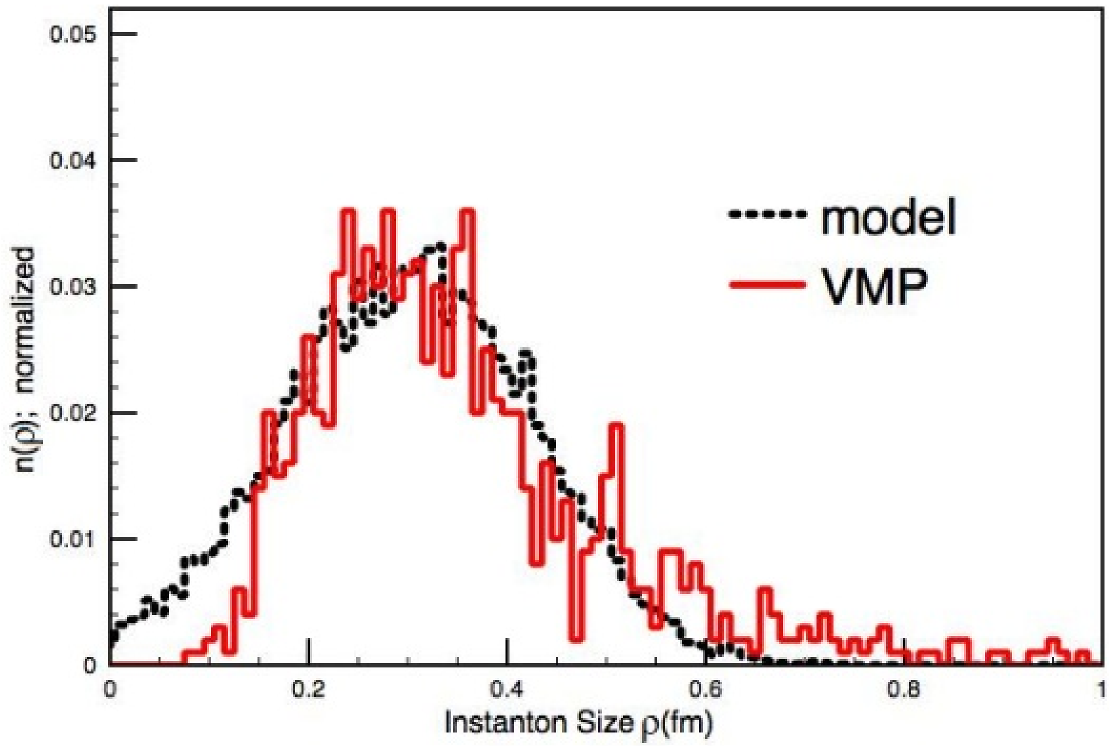




- Action density of the periodic instanton with trivial holonomy as function of z, t at fixed $x = y = 0$.

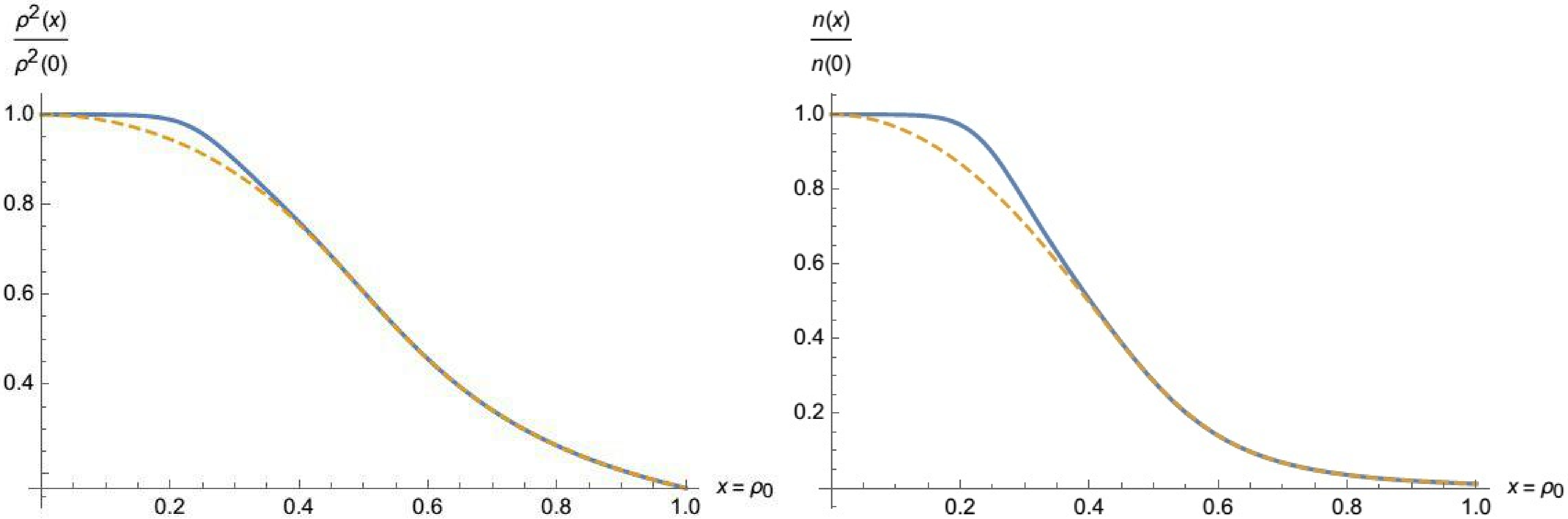
Intanton Liquid Model in QCD

- The ILM manages to describe all the nonperturbative physics using only two main parameters the avarage instanton size $\bar{\rho}$ and density n.
- Phenom.(Shuryak1981), Var.(Diakonov-Petrov1983) $n^{-1/4} = R \approx 1fm$, $\rho \approx 0.33fm$; Lattice(Negele1999): $R \approx 0.89fm$, $\rho \approx 0.36$ Our with $1/N_c$ corr: $R \approx 0.76, \rho \approx 0.32$



ILM at $T \neq 0$

- The figure on the left represents ratio of instanton sizes $\bar{\rho}^2(x)/\bar{\rho}^2(0)$ while right one ratio of instanton densities $n(x)/n(0)$ as functions of $x = \bar{\rho}_0 T$ corresponding to the variational estimates from Refs.[E.Shuryak and others,SeungilNam] at the phenomenological values of $\bar{\rho}(0) = 1/3\, fm$ and $n(0) = 1\, fm^{-4}$.



- Periodic scalar "gluon" propagator in periodical instanton field is

$$\Delta_I^{ab}(x,y) = \Delta_0^{ab}(x,y) + \Delta_1^{ab}(x,y) + \Delta_2^{ab}(x,y)$$

$$\Delta_0^{ab}(x,y) = 1/2\,\mathrm{tr}\frac{\tau_a F(x,y)\tau_b F(y,x)}{\Pi(x)4\pi^2(x-y)^2\Pi(y)}$$

$$F(x,y) = 1 + \sum_m \frac{\rho^2(\tau x_m)(\tau^+ y_m)}{x_m^2 y_m^2},$$

$$\Delta_1^{ab}(x,y) = 1/2\,\mathrm{tr}{\sum_m}' \frac{\tau_a F(x,y_m)\tau_b F(y_m,x)}{\Pi(x)4\pi^2(x-y_m)^2\Pi(y)}$$

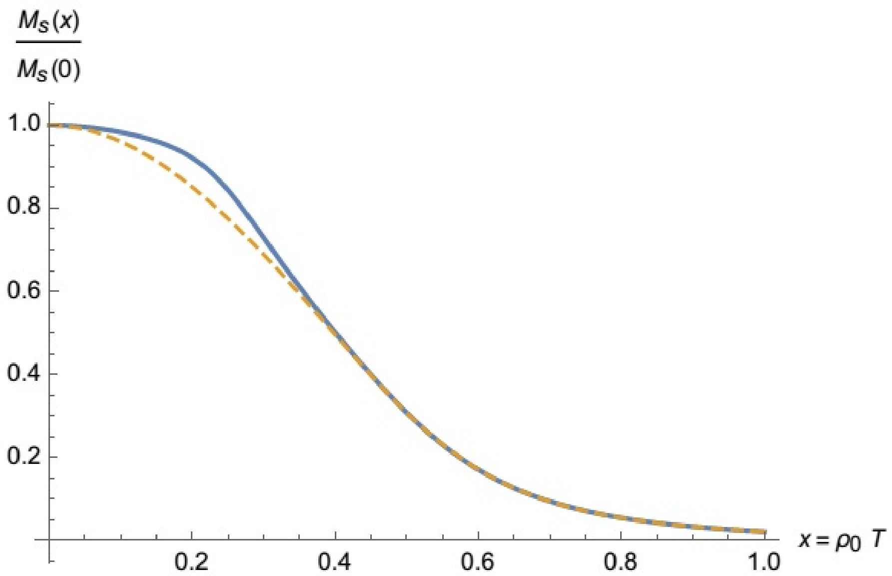
$$\Delta_2^{ab}(x,y) = \sum_m \frac{C^{ab}(x,y_m)}{\Pi(x)4\pi^2\Pi(y)},$$

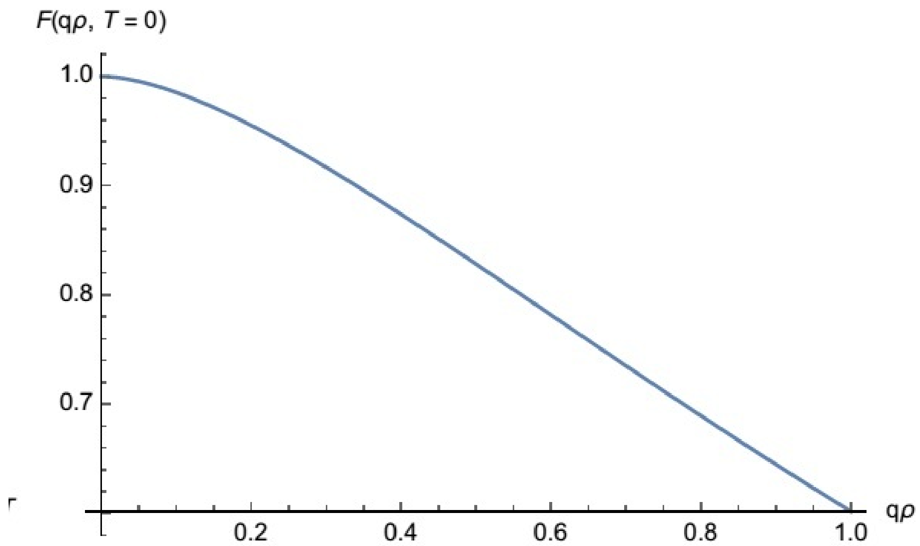
$$\sum_m C^{ab}(x,y_m) == \sum_{r\neq s} \frac{\rho^2 x^a}{x_r^2 x_s^2} \sum_m \frac{\rho^2 y^b}{y_{r+m}^2 y_{s+m}^2}$$

Gluons at $T \neq 0$

- Solve zero mode problem;
- Average gluon propagator in ILM by means Pobylitsa Eq. and find dynamical electric gluon mass $M_g(q,T)$

$$M_s(q,T) \approx M_{s,0,1}(q,T) = [\frac{3\bar{\rho}^2(T)n(T)}{(N_c^2-1)} 4\pi^2]^{1/2} F(q,T),$$
$$F(0,0)=1,\ F(q,T) \leq F(q,0) = q\bar{\rho}K_1(q\bar{\rho}).$$





Ratio of $M_s(x)/M_s(0)$ profile function F(T=0)

- Relation between real and scalar color field propagators mass is $M_{el}(0,0) = 2^{1/2} M_s(0,0) = 362\, MeV$
- Here $x = T\rho, x_c = 0.25, M_g(x) = M_g(0.T)$, M_g-strengh of gluon-instanton interaction.

Discussion

- $Q\bar{Q}$ and QCD vacuum properties are correlates very much. QCD vacuum = ILM is applicable for the $Q\bar{Q}$, since instanton average size $\rho \sim 1/3fm \sim Q\bar{Q}$ sizes, while density $n \sim 1fm^{-4}$.
- In ILM at $T \neq 0$ $\rho(T)$ and $n(T)$ are gradually decreasing functions which lead to essential changes of ILM contributions to $Q\bar{Q}$ potential. They must be taken into account in analysis of heavy quarks production processes
- We applied our result to the calculations of temperature dependencies of the heavy quarkonium properties.

Thanks for attention!!!