DYNAMICAL FORMATION OF CENTER DOMAINS IN QUARK-GLUON PLASMA

Jakapat Kannika

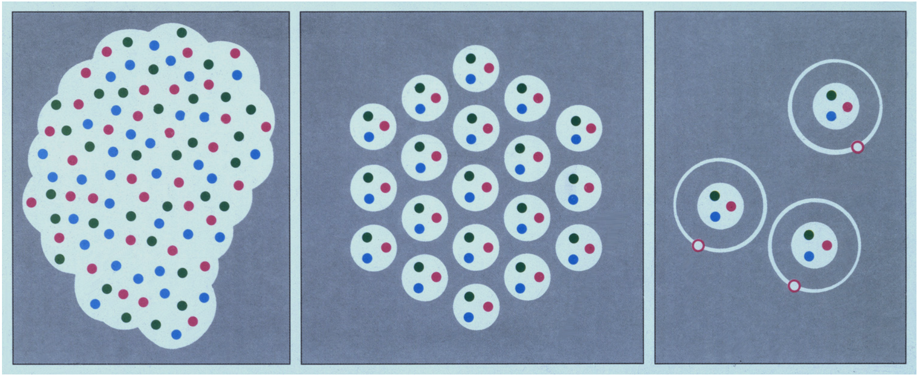
School of Physics, Institute of Sciences

Suranaree University of Technology

Advisor: Dr.Ayut Limphirat, Co-advisor: Dr.Christoph Herold

July 9, 2015

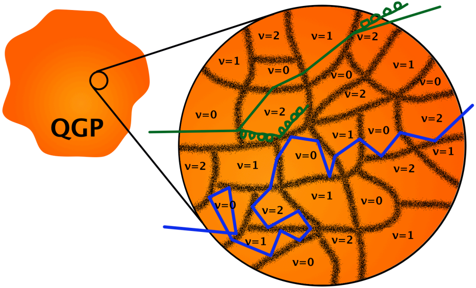
QGP, Hadron, Atom



Source: http://wwwae.ciemat.es/postscript/begona_complu_1.html

Center domains (1)

Center domains are domains that form from spontaneous breakdown of center symmetry where each domain is characterized by a finite value of the Polyakov loop.



Source: [Asakawa et al., 2013]

Center domains (2)

Center domains are claimed to be able explain to important properties of QGP [Asakawa et al., 2013]

1. Low ratio of shear viscosity to entropy density η/s,
2. Jet quenching.

Our research

We develop fully dynamical model from Polyakov loop potential and phenomenological kinetic term to explain microscopic behavior and investigate formation and decay of center domains in QGP.

Polyakov loop potential

From fitting the lattice QCD of pure gluon QCD,

we have a potential [Asakawa et al., 2013]

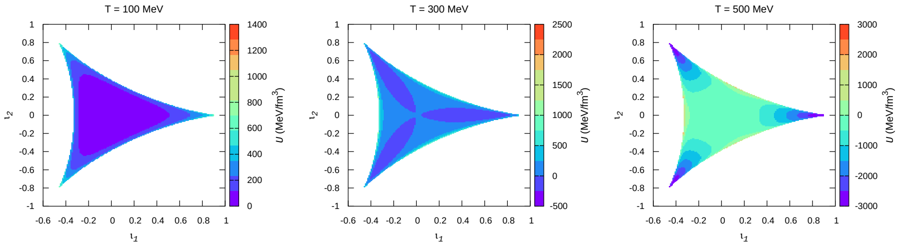
$$U(L) = -bT[54e^{-a/T}|L|^2 + \ln \mathrm{P}(L, L^{\dagger})], \qquad (1)$$

where L is Polyakov loop, T is temperature,

$a = 0.664\ GeV,\ b = 0.0075\ GeV^3,$

$\mathrm{P}(L, \bar{L}) = 1 - 6|L|^2 - 3|L|^4 + 4(L^3 + \bar{L}^3).$

Contour plot of the Polyakov loop potential



Construct a Lagrangian

From phenomenological Lagrangian density, we can naively guess a kinetic term

$$\mathcal{L} = \frac{\sigma}{2} T_c^2 \partial_\mu L \partial^\mu \bar{L} - U(L, \bar{L}) \tag{2}$$

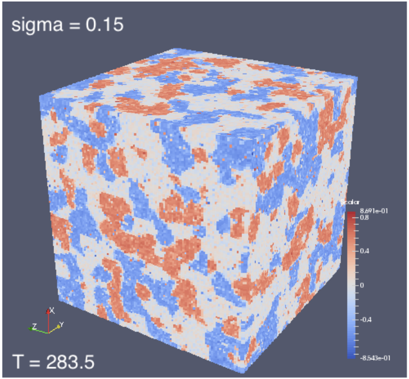
Derive the equations of motion

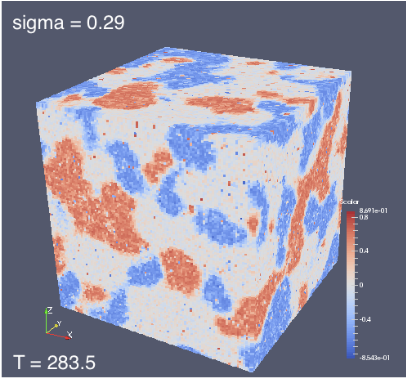
From Polyakov loop potential and phenomenological kinetic term we can get two equations of motion where $L = \ell_1 + i\ell_2$

$$\sigma T_c^2 \partial_\mu \partial^\mu \ell_1 + \frac{\partial}{\partial \ell_1} U(\ell_1, \ell_2) = 0 \tag{3}$$

$$\sigma T_c^2 \partial_\mu \partial^\mu \ell_2 + \frac{\partial}{\partial \ell_2} U(\ell_1, \ell_2) = 0 \tag{4}$$

Sigma coefficient and size of cluster



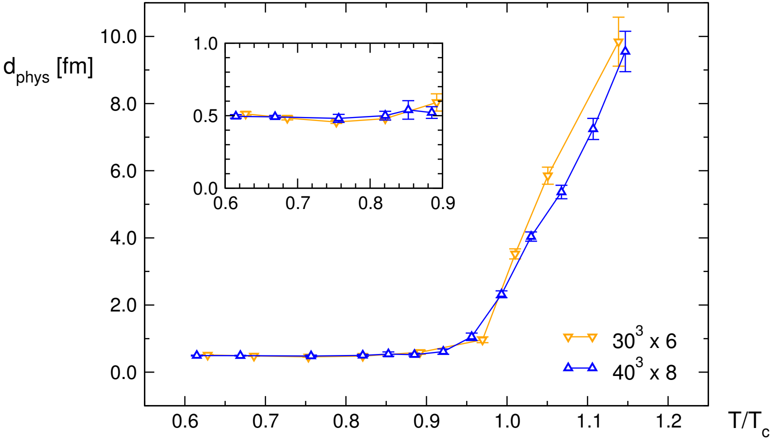


Fit Sigma

$$\sigma T^2 \partial_\mu \partial^\mu \ell_1 + \frac{\partial}{\partial \ell_1} U(\ell_1, \ell_2) = 0 \tag{5}$$

$$\sigma T^2 \partial_\mu \partial^\mu \ell_2 + \frac{\partial}{\partial \ell_2} U(\ell_1, \ell_2) = 0 \tag{6}$$

Fit Sigma (2)



Source: [Borsanyi et al., 2011]

Fitting sigma procedure

1) Fix T

2) Fix guessing σ

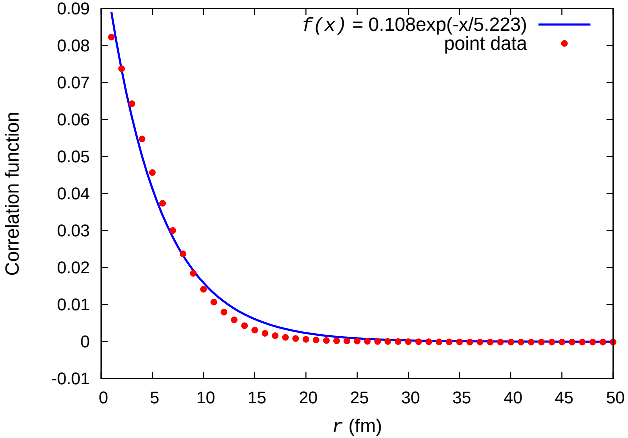
3) Run simulation

4) Calculate domain size.

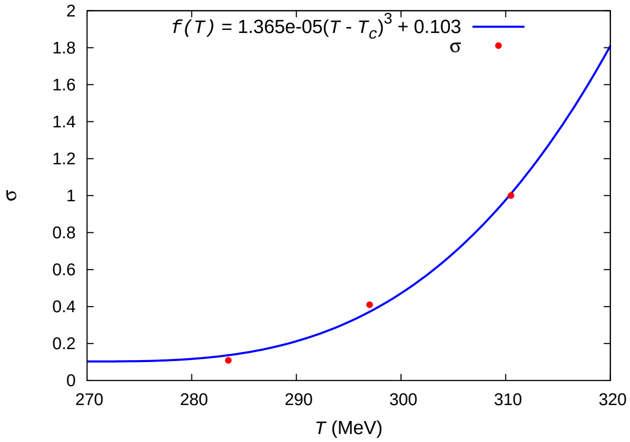
5) Compare calculated domain size to graph.

e.g. At $T = 1.1\,T_c = 310.5\ MeV$, $d_{phys} = 9.7\ fm$

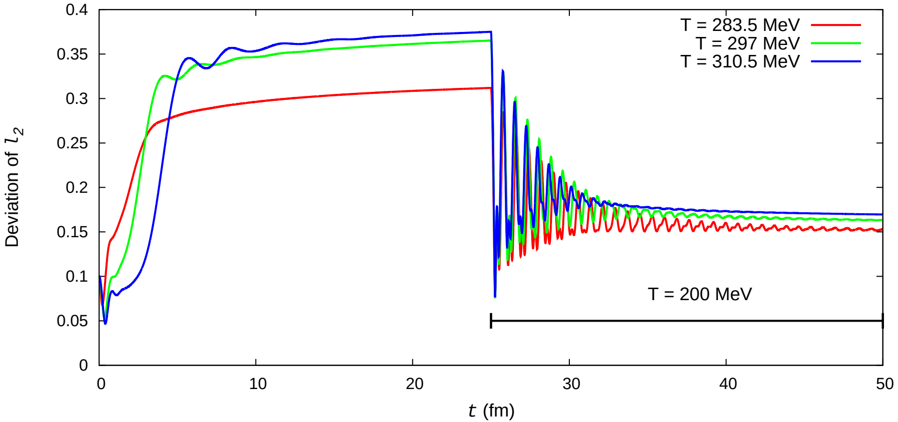
Graph of correlation function



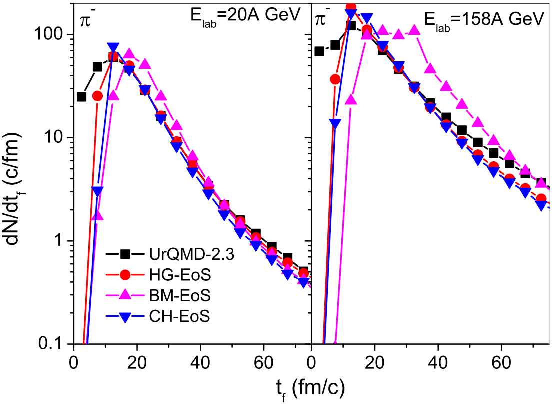
Result of Finding and Fitting Sigma Coefficient



Evolution of Center Domains: Deviation vs t



Freeze-out time



Source: Source: [Li et al., 2009]

Conclusions

- We can successfully construct the fully dynamical model of Polyakov loop.

- We can investigate the formation and decay of center domains.

- The formation time of center domains is shorter than a life-time of QGP in heavy-ion collision.

- Changing of temperature to $T < T_c$ bring a system return to confinement corresponding to heavy-ion collision.

References I

Asakawa, M., Bass, S. A., and Müller, B. (2013). Center domains and their phenomenological consequences. *Phys. Rev. Lett.*, 110:202301.

Borsanyi, S., Danzer, J., Fodor, Z., Gattringer, C., and Schmidt, A. (2011). Coherent center domains from local Polyakov loops. *J.Phys.Conf.Ser.*, 312:012005.

References II

Li, Q., Steinheimer, J., Petersen, H., Bleicher, M., and Stöcker, H. (2009). Effects of a phase transition on {HBT} correlations in an integrated boltzmann hydrodynamics approach. *Physics Letters B*, 674(2):111 – 116.

Acknowledgements

- Dr.Ayut Limphirat
- Dr.Christoph Herold
- All Lecturers
- SUT Nuclear and Particle Physics Group
- OROG Scholarship