Meson turbulence at quark deconfinement from AdS/CFT†

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How the quarks are confined at the vacuum of quantum chromodynamics (QCD) is one of the most fundamental questions in the standard model of particle physics. We would like to find a universal feature of the deconfinement. To understand the nature of the quark confinement, we need a proper observable which exhibits a universal behavior irrespective of how we break the confinement. In this paper, we propose a universal behavior of resonant mesons and name it *meson turbulence*.

Following our previous paper[1)], we find that a particular behavior of resonant mesons (excited states of mesons) can be an indicator of the deconfinement. The meson turbulence is a power-law scaling of the resonant meson condensations. For the the resonant meson level n $(n = 0, 1, 2, \cdots)$, the condensation of the meson $\langle c_n(x,t)\rangle$ with its mass ω_n causes the n-th meson energy ε_n scaling as $(\omega_n)^\alpha$ with a constant power α. This coefficient α will be unique for a given theory, and does not depend on how one breaks the confinement. In particular, for the theory which we analyze in this paper, that is $\mathcal{N} = 2$ supersymmetric QCD with $\mathcal{N} = 4$ supersymmetric Yang-Mills as its gluon sector at large N_c at strong coupling, the universal power-law scaling parameter α is found to be

$$\langle \varepsilon_n \rangle \propto (\omega_n)^\alpha, \quad \alpha = -5\,. \tag{1}$$

where ε_n is the energy of the n-th meson resonance. Normally, for example at a finite temperature, the energy stored at the n-th level of the resonant meson should be a thermal distribution, $\varepsilon_n \propto \exp[-\omega_n/T]$. The thermal distribution is Maxwell-Boltzmann statistics, in which the higher (more massive) meson modes are exponentially suppressed. However, we conjecture that this standard exponential suppression will be replaced by a power-law near any kind of the deconfinement transitions. If we think of the meson resonant level n as a kind of internal momentum, then the energy flow to higher n can be regarded as a so-called weak turbulence. This is why we call the phenomenon meson turbulence, and the level n can be indeed regarded as a momentum in holographic direction in the AdS/CFT correspondence.

The reason we came to the universal power behavior is quite simple. We combined two well-known things,

- Mesons are excitations of an open QCD string.

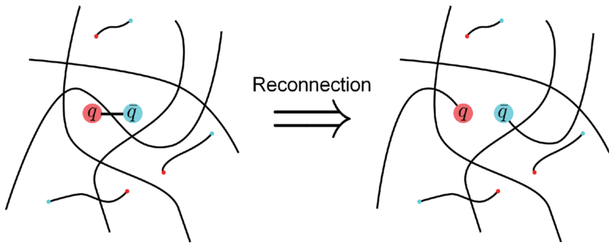

Fig. 1. A schematic picture of the deconfinement phase as condensation of QCD strings. Left: we add a meson (a pair of a quark and an anti-quark connected by a QCD string) to the system. Right: due to the background condensed QCD strings, the QCD string can be reconnected, and the quark can freely propagate away from the anti-quark.

- Deconfinement phase is described by a condensation of long strings.

Combining these two leads us to the conjecture that *the deconfinement of quarks is indicated by a condensation of higher meson resonances*. More precisely, we claim that *the condensation should be turbulent*: the higher mode condensation is not suppressed exponentially but behaves with a power-law.

We shall investigate various deconfining transitions in this paper, to check the universality of our conjecture of the meson turbulence. First, we work with a static case. A nonzero electric field is a good example since a strong electric field can make the quark-antiquark pair dissociate. Then we investigate time-dependent setup. The virtue of the AdS/CFT correspondence is that time-dependent analysis is possible, as opposed to lattice simulations of QCD. To demonstrate the universality of the meson turbulence, we work in two examples: (1) electric-field quench, and (2) quark-mass quench. In all cases, we find numerically the meson turbulence and the universal power law with the power $\alpha = -5$.

The universality we found in this paper strongly indicates that the meson turbulence is a universal phenomena which is independent of how one breaks the confinement.

References
1) K. Hashimoto, S. Kinoshita, K. Murata and T. Oka, arXiv:1408.6293 [hep-th].

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