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On aspects of holographic thermal QCD at finite coupling

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Abstract

In the context of string theoretic dual of thermal QCD-like theories at finite gauge/string coupling of [1] (as part of the 'MQGP' limit of [2]), we obtain the QCD deconfinement temperature compatible with lattice results for the right number of light flavors $N_f = 3$, and the correct mass scale of the light (first generation) quarks. The type IIB background of [1] is also shown to be thermodynamically stable. Further, we show that the temperature dependence of DC electrical conductivity mimics a one-dimensional Luttinger liquid, and the requirement of the Einstein relation (ratio of electrical conductivity and charge susceptibility equal to the diffusion constant) to be satisfied requires a specific dependence of the Ouyang embedding parameter on the horizon radius. These results arise due to the non-Kählerity and non-conformality of the type IIB background. On the geometrical side we quantify the former (non-Kählerity) by evaluating the $SU(3)/G_2$-structure torsion classes of the local type IIA mirror/M-theory uplift. Analogous to what was shown for the type IIB background in [5], we first show that the type IIA delocalized SYZ mirror (after fine tuning) can also be approximately supersymmetric. We then work out the G_2-structure torsion classes of the local M-theory uplift of the mirror type IIA metric – in the large-N limit at finite coupling, G_2 structure approaches G_2 holonomy.

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1. Introduction and motivation

In recent years it has been realized that the problem of strongly coupled gauge theories is best tackled by the gauge/string duality. One of the remarkable examples of this duality is the AdS/CFT correspondence [4] conjectured by Maldacena in 1997. According to this correspondence type IIB superstring theory in $AdS_5 \times S^5$ is dynamically equivalent to the four dimensional $SU(N)$ Yang–Mills theory with large N and $\mathcal{N} = 4$ supersymmetry. This correspondence is actually based on the so-called holographic principle: information of the bulk of dimension d is mapped to a $d-1$ dimensional theory living on the boundary. A generalization of the AdS/CFT correspondence was required to gain a deeper insight into QCD. In particular, efforts have been made to relax some of the constraints such as conformal symmetry of the gauge theory which was necessary for the validity of the correspondence. In fact it is believed that strongly coupled thermal QCD 'laboratories' like strongly coupled Quark Gluon Plasma (sQGP), apart from having a large 't Hooft coupling, *must also be characterized by finite gauge coupling [3]*. It is hence important to have a framework in the spirit of gauge-gravity duality, to be able to address this regime in string theory. *Finite gauge coupling would under this duality translate to finite string coupling hence necessitating addressing the same from an M theory perspective.* This was initiated in [2] and [5].

In this work, using the top-down holographic thermal QCD model of [1], we have discussed some QCD-related properties at finite temperature, and most importantly, *at finite gauge coupling*.[1] It is largely in this respect that through this paper we will attempt to fill in an important gap by studying *at finite gauge coupling* (as part of the 'MQGP limit' of [2]) for the first time:

- Physics-related issues such as:
  - evaluation of lattice-compatible T_c for the right number and masses of light quarks,
  - demonstrating the thermodynamical stability of [1],
  - obtaining the temperature dependence of electrical conductivity σ, charge susceptibility χ and hence seeing the constraints which the Einstein's law (relating $\frac{\sigma}{\chi}$ to the diffusion constant) imposes on the holomorphic Ouyang embedding of $D7$-branes into the resolved warped deformed conifold geometry of [1];
- Math-related issues such as:
  - quantifying the non-Kählerity (which is what influences the Physics issues alluded to above) of the delocalized Strominger Yau Zaslow (SYZ) type IIA mirror of [1] constructed in [2] by evaluating the $SU(3)$ structure torsion classes (the same for the type IIB background of [1] were evaluated in [5]),
  - evaluating the G_2-structure torsion classes, and hence obtain for the first time, an explicit G_2-structure of the M-theory uplift of the type IIB holographic model of [1].

The Math issues, as explained a bit later in this section and elaborated upon towards the end of Sections 3 and 5.1 as well as 5.2, are not only a precise way of helping one understand the inherent non-Kählerity of the holographic model of [1] and its mirror constructed in [2] which is what largely influences the Physics issues, but also explicitly shows the existence of approximate supersymmetry in the MQGP limit justifying the construction of the delocalized SYZ type IIA mirror in [2]. *This two-pronged approach in understanding large-N thermal QCD with funda-*

[1] Note however, this is not a paper on QGP.