

## 論文内容の要旨

論文題目 Correlation Functions with D-branes in Gauge/String Correspondence

ゲージ・ストリング対応におけるDブレーンを伴う相関関数

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### Abstract

In this thesis we study  $AdS_5/CFT_4$  correspondence and its applications on the half-BPS sector preserving sixteen supercharges. The AdS/CFT correspondence under consideration is the most familiar one, namely, type IIB superstring theory on  $AdS_5 \times S^5$  and a maximally supersymmetric gauge theory (superconformal Yang-Mills theory) in four dimension. We focus on a special sector of gauge theory that contains gauge-invariant operators, i.e. half-BPS circular Wilson loops and half-BPS chiral primary operators, which can be represented as D-brane excitations on the dual bulk side.

Two main spotlights in this thesis are holographical Wilson/Polyakov loop correlators and giant graviton (half-BPS chiral primary operator) correlators in terms of non-critical  $c = 1$  string theory. That is, we consider their large 't Hooft coupling behaviors using classical gravity (or string) theory.

In the former case, the correlator preserves no supersymmetry and its strong coupling limit is predicted from an F-string/D-brane system in  $AdS_5 \times S^5$  geometry. On the other hand, the latter case has no dependence on gauge couplings, hence its rigorous result can be deduced exactly through a complex matrix model. In spite of this, we uncover a correspondence between this correlator and tachyon scatterings in non-critical  $c = 1$  string theory. This relation can be thought of as a topological feature behind the highly supersymmetrically protected sector of super Yang-Mills.

### An overview

#### Chapter 2

The starting point is devoted to an introduction of AdS/CFT correspondence. That is, gravity can be identified as gauge theory in certain parameter region and ultimately to all

regions. We analyze AdS/CFT correspondence from two aspects. We first consider the dual geometry  $AdS_5 \times \mathcal{M}_5$  when  $\mathcal{M}_5 = S^5$ . This is the standard prototype of AdS/CFT, which has received most attention so far. Its finite temperature (or non-extremal) cousin, which will be adopted in chapter five, is also covered. Unlike the above extremal zero-temperature case, at finite temperature, the ratio of inverse temperature to the radius of  $S^5$  serves as a reference for the occurrence of Hawking-Page phase transition. This phenomenon is interpreted as confinement/deconfinement transition in the gauge theory context.

Secondly, a less supersymmetric  $\mathcal{M}_5 = T^{1,1}$  base manifold is chosen to demonstrate another example of AdS/CFT. We will use its dual gauge theory known as a quiver type one in chapter six. The reason is that the gauge theory moduli space is just the transverse Calabi-Yau cone-conifold and shares many key features with topological strings on the conifold. In addition, since one can obtain smooth  $T^{1,1}$  by blowing up an orbifold  $S^5/\mathbb{Z}_2$ , we show that this process amounts to break sixteen supercharges to eight ones through turning on a mass deformation on the field theory side.

### Chapter 3

In this chapter, we include various materials to illustrate the intimate relationship between three-dimensional Chern-Simons gauge theory and  $\mathcal{N} = 4$  SYM, concerning Wilson loops. They serve as basic building blocks of this thesis. First of all, we introduce Ooguri-Vafa operator, which best shows how holographical brane configurations can be, more or less, predicted from pure gauge theory considerations, namely, Wilson loop generating function.

Based on this, we go to review the construction of holographical duals of half-BPS circular Wilson loops. In the case of D5-branes embedded in  $AdS_5 \times S^5$ , first proposed by Satoshi Yamaguchi, the construction itself bears a strong resemblance to baryon vertices found by Witten soon after Maldacena's AdS/CFT. By restricting ourselves to half-BPS Wilson loops, an exact gauge calculation is possible because supersymmetry protection controls all quantum corrections. This is carried out by the so-called "Gaussian matrix model". We review this reduced model and, by taking large 't Hooft coupling limit, an interpolation can be made for strong coupling regime where the perfect match with gravity result is shown.

Finally, we discuss some features shared by Chern-Simons gauge theory and  $\mathcal{N} = 4$  SYM. The main idea is that on both sides there are *bubbling* geometries due to a large number of probe branes, i.e. they backreact on the original  $AdS_5 \times S^5$  and the resulting modified geometry is one-to-one identified with a fermion droplet picture. This fascinating description can be summarized as a "Maya-geometry correspondence". Here, Maya diagrams arise from Young tableaux which ultimately classify all free fermion droplets from matrix models. Moreover, the matrix model can be either the above Gaussian one

or a Kontsevich-type one appearing on the mirror topological B-model side.

## Chapter 4

This chapter analyzes in detail two Wilson loop correlators, following the work of myself and Satoshi Yamaguchi. Their gravity duals are proposed as F-string/D-brane systems and their phase structures are studied thereof.

## Chapter 5

This chapter extends the analysis of two temporal Wilson loop correlators to finite temperature case. In this case, the gravity dual becomes an F-string/D-brane system embedded in the *AdS* black hole geometry. As well, the phase structures is studied thereof.

## Chapter 6

This chapter is devoted to discuss another kind of gauge/string correspondence. That is, a special (half-BPS) sector in  $\mathcal{N} = 4$  SYM is mapped to non-critical  $c = 1$  strings. The main result is the finding that both  $S$ -matrices are exactly the same up to a parameter map. Although the reason is still obscure, we can only say that it is again supersymmetry protection that makes only topological information survives, which is insensitive to fluctuations. This statement is then supported by an equivalence between  $c = 1$  string theory at self-dual radius and topological strings on the simplest Calabi-Yau cone-conifold.

To say more on this point, we introduce some backgrounds of B-model topological strings and its dual (Dijkgraaf-Vafa or Kontsevich) matrix model description. Since DV model is known to be dual to the far infrared-red (IR) region of certain  $\mathcal{N} = 1$  gauge theory in confining phase, we find an interesting tri-ality between  $\mathcal{N} = 1$ ,  $c = 1$  and topological strings. This observation in turn sheds light on a future work we will mention later.

## Chapter 7

We give conclusions and address two relevant points as our concluding remarks of this thesis. We propose an observation concerning Nekrasov's instanton counting from  $c = 1$  perspective. This may be thought of as a by-product of the preceding tri-ality because holomorphic information of  $\mathcal{N} = 2$  Seiberg-Witten theory, i.e. the prepotential including instanton corrections, still survives in the descending  $\mathcal{N} = 1$  theory dual to  $c = 1$  strings as stressed.

Another aspect is an application of the aforementioned Dijkgraaf-Vafa-Kontsevich

duality. We show its physical meaning can be interpreted as “Seiberg duality”<sup>1</sup>, which manifests an electric-magnetic duality for  $\mathcal{N} = 1$  gauge theory with matters. This part is based on the discussion with Kazutoshi Ohta.

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<sup>1</sup>Roughly speaking, a proposed weak-coupling theory at IR plays the complimentary role for another UV free but IR strongly-coupling  $\mathcal{N} = 1$  gauge theory.