

# 1 Scientific Report

The workshop took place July 21-25 at Queen Mary, University of London. Full details of the programme, titles and abstracts are available at <http://ph.qmul.ac.uk/meetings-and-workshops/permutations-and-gauge-string-duality-2014> The titles and abstracts are also listed below. The speakers included participants from the USA (Prof. Jevicki, Dr Lin), Germany (Dr. Sieg), Denmark (Dr. Harmark), Japan (Dr. Kimura) as well as a number from London and the UK. There were 4 talks a day on most days, and a total of 17 talks. There was plenty of time for discussions after each talk, and during informal lunch breaks and dinners. Several outstanding problems and ideas for future research were mentioned during the talks and the discussions. The meeting was particularly useful as a bridge between physicists with experience in planar integrability, wrapping interactions (e.g Torrielli, Sieg, Suzuki) and those working on finite N effects with Young diagram methods ( e.g. Ramgoolam, de Mello Koch, Kimura). I expect there will be progress on the properties of the one-loop dilatation operator in the  $SU(2)$  and  $SO(6)$  sectors of  $N = 4$  SYM as a consequence of conversations that have happened here. Other prominent lines of conversations included the interplay between the TFT2 approach to CFT4 (talk by Ramgoolam) and higher spin theories (talk by Jevicki).

## 1.1 Speakers, Titles, Abstracts

### **Pablo Diaz : Restricted Schur basis for classical gauge groups in CFT's and correlators via Weingarten calculus**

**Abstract:** For 1/2 BPS operators, a Schur basis for classical gauge groups has been recently found to be intimately related to a special (the simplest) embedding of theories:  $G(N) \rightarrow G(N+1)$ , where  $G(N)$  is the gauge group. In this talk we will extend this notion to generic operators. We will find new operators associated with the embedding for which the restricted Schur basis emerges naturally as their eigenvectors and the correlators of elements of the restricted Schur basis are encoded in their eigenvalues. We will also briefly discuss how other embeddings lead to different bases.

### **David Garner - Thresholds of factorisation in $AdS_5/CFT_4$**

**Abstract:** Large N factorisation in N=4 Super Yang-Mills states that the correlators of distinct half-BPS trace operators of low dimension vanish

at large  $N$ . These operators are dual to low energy excitations of gravitons moving in the compact directions of the bulk  $AdS_5 \times S^5$ , which form a Fock space structure. If the dimensions of the operators are instead taken to be large with respect to  $N$ , then the correlators grow large and the Fock space description of the dual graviton excitations is no longer valid. The threshold energy scales at which factorisation fails to hold can be found by considering exact finite- $N$  calculations of extremal and non-extremal CFT correlators. Quite generally, the threshold scale is where the product of the operator dimensions of two holomorphic traces is of order  $N \log N$ . Using the UV/IR relation, the graviton energies can be related to distance scales in the bulk. The non-vanishing quantum correlations between gravitons at distinct bulk positions can be interpreted as a sign of the emergence of non-local quantum gravity effects at the threshold.

**Troels Harmark - Spin matrix theory: A quantum mechanical model for the AdS/CFT correspondence**

**Yang Hui He - Eta Products, BPS States and K3 Surface**

**Abstract:** Inspired by the multiplicative nature of the Ramanujan modular discriminant,  $\Delta$ , we consider physical realizations of certain multiplicative products over the Dedekind eta-function in two parallel directions: the generating function of BPS states in certain heterotic orbifolds and elliptic K3 surfaces associated to congruence subgroups of the modular group. We show that they are, after string duality to type II, the same K3 surfaces admitting Nikulin automorphisms. In due course, we will present some identities arising from  $q$ -expansions as well as relations to the sporadic Mathieu group  $M_{24}$ .

**Antal Jevicki - Reconstructing Higher Spin Holography**

**Abstract:** The bi-local picture of  $O(N)$  vector CFT is used for construction of Higher Spins in AdS. Recent 1-loop calculations relating to thermodynamics will be discussed. The 'gauge' origin of holography in HS theories will be outlined.

**Yusuke Kimura - Noncommutative Frobenius algebras and open strings**

**Abstract:** I will study noncommutative Frobenius algebras constructed from the symmetric groups and Brauer algebras. Based on the relation between Frobenius algebras and 2D topological field theories, I will discuss how open

strings can be described by the algebras. Robert de Mello Koch - Higher Loop Anomalous Dimensions from Symmetry Abstract: We study the action of the one loop dilatation operator on operators with a classical dimension of order  $N$ . These operators belong to the  $su(2)$  sector and are dual to excited giant graviton states. Non-planar diagrams contribute already at the leading order in  $N$  and the planar and large  $N$  limits are distinct. The action of the one loop and the two loop dilatation operator reduces to a set of decoupled oscillators. Using the  $su(2)$  symmetry we give evidence that this continues to any loop order.

**Hai Lin - Relation between giant gravitons, large operators and integrability**

**Andrea Prinsloo - Giant gravitons on  $AdS_3 \times S^3 \times S^3 \times S^1$**

**Abstract:** I will describe the construction of various 1/4-BPS D1 and D5-brane giant gravitons embedded into the type IIB supergravity background  $AdS_3 \times S^{3+} \times S^{3-} \times S^1$  with pure R-R flux. These D-branes are supported by angular momenta  $\alpha P$  on one 3-sphere and  $(1 - \alpha)P$  on the other. I will then construct a general class of 1/8-BPS D5-brane giant gravitons wrapping 4-cycles  $\Sigma$  in  $S^{3+} \times S^{3-}$  and the  $S^1$ . Here  $\Sigma$  is the intersection of a holomorphic surface in  $C^{2+} \times C^{2-}$  with the  $S^{3+} \times S^{3-}$  submanifold. This holomorphic surface is defined by  $f(y_1z_1, y_1z_2, y_2z_1, y_2z_2) = 0$ , with  $y_a$  and  $z_a$  the  $C^{2+}$  and  $C^{2-}$ -complex coordinates. There is supersymmetry enhancement to 1/4-BPS for the subclass with  $f(y_1, z_1) = 0$ .

**Sanjaye Ramgoolam - CFT4 from TFT2**

**Abstract:** Four dimensional conformal field theory correlators can be expressed in terms of  $SO(4,2)$ -invariant linear maps defining a two-dimensional topological field theory. The state spaces of the TFT2 involve both highest and lowest weight representations of the conformal algebra. Crossing symmetry in four dimensions is related to associativity in two dimensions, which is in turn interpreted in terms of topological equivalence of cobordisms. This is described concretely in the case of the free scalar field. Counting problems on the spectrum of primaries in the four dimensional theory can also be expressed in terms of two dimensional topological field theories.

**Rodolfo Russo - Entanglement entropy and black hole microstates**

**Abstract:** The D1-D5 CFT provides a dual description for the Strominger Vafa black hole. I will focus on semi-classical BPS states in this AdS/CFT

duality and describe how to calculate the entanglement entropy of a single interval from both the holographic and the CFT point of view. I will show that this quantity depends on the specific state considered and discuss how it can be used to characterise the black hole microstates.

**Christof Sieg - Finite-size effects in the gamma\_i-deformed  $N = 4$  SYM theory**

**Abstract:** In this talk, I will explain how finite-size corrections originate from certain types of non-planar diagrams. In the  $N=4$  SYM theory these are the wrapping diagrams, and they affect the planar spectrum when the loop order matches or exceeds the length of the external states. In the gamma\_i-deformation, which was proposed as the conformal field theory in a non-supersymmetric deformation of the AdS/CFT correspondence, an additional type of finite-size correction arises. It occurs one loop order before wrapping and is connected to double-trace couplings. Since these couplings are running, the planar spectrum becomes scheme dependent and conformal invariance is broken – even in the planar limit.

**Joan Simon - Black holes, entanglement and random matrices**

**Abstract:**

Quantum entanglement and typicality play a crucial role to understand the foundations of statistical mechanics. Recently, it has been suggested that the former is also relevant to explain the connectedness of spacetime. In particular, a direct relation between semiclassical wormholes and quantum entanglement has been conjectured. In this talk, I will first discuss some necessary, but not sufficient, conditions that correlation functions of low energy gravity probe operators must satisfy to allow an interpretation in terms of a semiclassical wormhole. I will then study typicality of these correlators in the space of quantum states having the same amount of entanglement. To compute these correlators I will argue that low energy gravity probe operators behave like random matrices when acting on the space of black hole microstates. I will conclude that typical entangled states do not allow a semiclassical wormhole interpretation.

**Ryo Suzuki - The spectrum of tachyons in the Giant-antigiant system**

**Abstract:** I will describe different techniques to calculate the spectrum of strings between a D-brane anti-D-brane pair in  $AdS_5 \times S^5$ . The particular

example will be made of two maximal giant gravitons. I will do a perturbative gauge theory calculation as well as introduce the tools of integrability to evaluate the spectrum and try to identify the tachyonic mode.

**Alessandro Torrielli - Secret Yangian symmetries in  $AdS_n$**

**Abstract:** We report on the issue of a hidden Yangian symmetry which seems to accompany the AdS/CFT integrable structures in various dimensions (most notably  $n=5,4,3$ ), and whose quantum group origin has only recently begun to be elucidated.

**Donovan Young - Three-Point of Chiral Primary Operators and Giant Gravitons in AdS/CFT**

**Abstract:** In this talk I will discuss calculations of three-point functions involving two giant gravitons and one point-like graviton in  $AdS_5 \times S^5$  and in ABJM, and also discuss the three-point function of point like gravitons, i.e. chiral primary operators in ABJM at weak and strong 't Hooft coupling.