Utrecht University Network Node

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3rd RTN Workshop
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Quantum Gravity, strings and elementary particles

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Research areas

- Quantum Gravity
- Particle Physics/QCD
- Cosmology
- Super-symmetric black holes
- Physics of instantons
- Integrability on AdS/CFT and related issues
  - Integrability of physical strings on $AdS_5 \times S^5$
  - S matrix of strings on $AdS_5 \times S^5$, finite size corrections, ect
  - Operators with large spin, BES equation
  - Scattering amplitudes

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- Integrability on AdS/CFT and related issues
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  - AdS/CFT S matrix, finite size corrections.
  - Operators with large spin, BES equation (today)
  - Scattering amplitudes (Friday)

Large spin operators

Consider a massless gauge theory

Twist two operators

$$\mathcal{O}_S = Tr(\phi D^S \phi), \qquad S \gg 1 \qquad \Rightarrow \qquad \Delta_{\mathcal{O}_s} = f(g) \log S + \mathcal{O}(1)$$

$f(g)$: Cusp anomalous dimension, scaling function, etc.

- Anomalous dimension of large Lorentz spin operators.
- Expectation value of Wilson loops with a cusp.
- Scattering amplitudes.

It is hard to compute $f(g)$ for QCD, we can try computing it for a simpler theory, as for instance, planar $\mathcal{N} = 4$ SYM. Many simplifications, in particular

- Planar $\mathcal{N} = 4$ SYM is supposed to be integrable, so we can hope to apply the tools of integrable systems to compute the cusp anomalous dimension. Besides, integrability serves as a strong moral support.
- By using the AdS/CFT duality, we can get results from the strong coupling side.

Integrability: The anomalous dimension of certain operators are computed by using some Bethe ansatz.

$$\Downarrow$$

An integral equation for $f(g)$ has been proposed

BES equation (Beisert, Eden, Staudacher)

$$f(g) = 8g^2 - \frac{8}{3}\pi^2 g^4 + \ldots$$

- Explicit computations confirm the BES equation up to four loops!! Bern, Czakon, Dixon, Kosover, Smirnov, Moch, Vermaseren, Vogt,...

AdS/CFT duality

$$\begin{array}{rcl} \text{Four dimensional} & & \text{Type IIB string theory} \\ \text{maximally SUSY Yang-Mills} & \Leftrightarrow & \text{on } AdS_5 \times S^5. \end{array}$$

- Compute $f(g)$ at strong coupling by considering strings spinning on AdS_5

σ-model computations Gubser, Klebanov, Polyakov, Frolov, Tseytlin, Roiban, Tirziu

$$f(g) = 4g - \frac{3\log 2}{\pi} + \frac{K}{4\pi^2}\frac{1}{g} + \ldots$$

Very recently people learnt how to deal with the BES equation at strong coupling, and found perfect agreement with the strong coupling result!! (Basso, Korchemsky, Kotanski)

- $f(g)$ is a non BPS quantity, of definite physical relevance, that can be extrapolated from weak to strong coupling, providing a highly non trivial test of many ideas: AdS/CFT, integrability, etc.

Future directions?

Operators with large spin S and large $SO(6)_R$ charge J

$$\mathcal{O} = Tr(\phi^k D^S \phi^{J-k}), \quad S, J \gg 1, \quad J/\log S = j$$

$$\Downarrow$$

$$\Delta_{\mathcal{O}} = (f(g) + \epsilon(g,j)) \log S$$

- Most of $\epsilon(g,j)$ is given by an $O(6)$ bosonic $\sigma-$model! , in particular, there is a prediction for string theory at all loops (L.F.A., J. Maldacena).