AdS_3/CFT_2 : Moduli and wrapping

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Based on work with D. Bombardelli, O. Ohlsson Sax and A. Torrielli, arXiv:1804.02023 [hep-th], arXiv:1807.07775 [hep-th].

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Plan

1. **Integrable AdS_3/CFT_2**

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2. **Moduli and Integrability**

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2. **Moduli and Integrability**
3. **Towards Wrapping in AdS_3/CFT_2**
4. **Outlook**

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  NSNS+RR charges (n.h. D1+F1/D5+NS5)
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- Integrability "works" means:
  Wsheet S matrix known exactly in α' or R_{AdS}, satisfies YBE
  S matrix fixed by famous central extension and crossing eqs
  Bethe Equations for asymptotic states: protected spectrum

Moduli and Integrability

$AdS_3 \times S^3 \times T^4$ Moduli

IIB string theory on T^4 has 25 moduli:

$$g_{ab}\,(\times 10), \quad B_{ab}\,(\times 6), \quad C_{ab}\,(\times 6), \quad C_0, \quad C_{abcd}, \quad \phi$$

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Integrable results found when moduli zero

What happens away from the origin of moduli space?

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E.g. Pure NSNS charge bkd has C_0 and C_2^+.

Turning on C_0 in NSNS $AdS_3 \times S^3 \times T^4$

Set C_0 to a non-zero constant.

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$$F_3 = dC_2 - C_0 H = -C_0 \, k \,\mathrm{vol}(\mathrm{S}^3) \neq 0$$

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Since $H \neq 0\,,$ $F_3 \neq 0$, and all other $F = 0$

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NSNS bkd integrable across moduli space away from $C_0 = 0$ point

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Pert. long strings appear - new sector in Hilbert space.

Moduli and Integrability of $AdS_3 \times S^3 \times T^4$

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R^2 and the coupling cst $h(R)$ depend on consequential moduli

Towards Wrapping in AdS_3/CFT_2

Wrapping Corrections in AdS_3

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In AdS_3 have massless states $m = 0$

Hard to understand finite L corrections [Abbott+Aniceto]

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Consider BMN limit

$$p_i \to \frac{p_i}{h}\,, \qquad h \to \infty$$

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At small p, massive/massive and massive/massless scattering has pert. expansion. Ditto massless left/massless right scattering.

Low energy S matrix in RR AdS_3

Massless/massless S matrix for wsheet l/l or r/r on the other hand

$$S_{l/l} = S^{(0)}_{l/l} + h^{-2} S^{(1)}_{l/l} + h^{-4} S^{(2)}_{l/l} + \dots$$

is non-trivial and non-diagonal even at leading order.

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Similar S matrices invastigated in the 90s by Zamolodchikov, Fendley and Intriligator, Dunning...

Dressing factor in low-energy limit

Dressing factors have an expansion

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$\sigma_{\mathrm{HL}}^2 \equiv e^{i\theta_{\mathrm{HL}}}$ reduces to

$$\theta_{\mathrm{HL}}^{\mathrm{rel}}(\vartheta) = \frac{2i}{\pi} \int_{-\infty}^{\infty} d\phi \frac{e^{\vartheta+\phi}}{e^{2\vartheta}+e^{2\phi}} \log\left(\frac{1-ie^{\phi}}{1+ie^{\phi}}\right) - \frac{\pi}{2}$$

$\vartheta = \theta_1 - \theta_2$ with $p_i = e^{\theta_i}$
as expected for a relativistic theory.

HL dressing factor in low-energy limit

$\sigma_{\mathrm{HL}}^{\mathrm{rel}}$ satisfies the famous sine-Gordon crossing equation

$$\sigma_{\mathrm{HL}}^{\mathrm{rel}}(\vartheta)\sigma_{\mathrm{HL}}^{\mathrm{rel}}(\vartheta + i\pi) = i \tanh \frac{\vartheta}{2}$$

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In physical strip $\sigma_{\text{HL}}^{\text{rel}}$ is equal to Zamolodchikov scalar factor in SG soliton/anti-soliton scattering (with $\gamma = 16\pi$, $\beta^2 = 16\pi/3$)

$$\sigma_{\text{HL}}^{\text{rel}}(\vartheta) = \prod_{l=1}^{\infty} \frac{\Gamma^2(l-\tau)\Gamma(l+\tau+1/2)\Gamma(l+\tau-1/2)}{\Gamma^2(l+\tau)\Gamma(l-\tau+1/2)\Gamma(l-\tau-1/2)}$$

where $\vartheta = 2\pi\tau i$

Relativistic Bethe Equations

The BEs reduce to (two copies of)

$$
\begin{aligned}
1 &= \prod_{j=1}^{K_0} \tanh \frac{\beta_{1,k} - \theta_j}{2}\,, \\
e^{iLp_k} &= (-1)^{K_0-1} \prod_{\substack{j=1 \\ j\neq k}}^{K_0} \sigma^2(\vartheta_{kj}) \prod_{j=1}^{K_1} \coth \frac{\beta_{1,j} - \theta_k}{2} \prod_{j=1}^{K_3} \coth \frac{\beta_{3,j} - \theta_k}{2}\,, \\
1 &= \prod_{j=1}^{K_0} \tanh \frac{\beta_{3,k} - \theta_j}{2}\,,
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Relativistic TBA for CFT$^{(0)}$

Introduce rapidity density $\rho_0 = \frac{\Delta n}{\Delta \theta}$, and analogously $\rho_{\pm 1,3}$ for level-1 magnons, (solutions come in pairs: [Fendley+Intriligator]

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$$\varepsilon_0 = \nu_0(\theta) - \sum_{n=1,3} \phi * (L_{+n} + L_{-n})\,; \quad \varepsilon_{\pm n} = -\phi * L_0,$$

where $\phi = \frac{\text{sech}\ \theta}{2\pi}$, $n = 1, 3$ and $A = 0\,,\, \pm n$

$$\nu_0(\theta) \equiv MR\, e^{\theta}\,, \qquad \varepsilon_A \equiv \log \frac{\rho_A^h}{\rho_A^r}\,, \qquad L_A \equiv \log(1 + e^{-\varepsilon_A})\,,$$

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The exact ground-state energy for right-movers is given by

$$E_{0,\mathrm{right}}(R) = -\frac{M}{2\pi} \int d\theta e^{\theta} \log(1 + e^{-\varepsilon_0(\theta)})\,,$$

Properties of CFT$^{(0)}$ from TBA

Ground-state energy with anti-peridodic boundary conditions for fermions (a.k.a. Witten's index) is zero.
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These properties suggest CFT$^{(0)}$ is just a free CFT on T^4 or R^4

Conclusions

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- Match short strings to Maldacena Ooguri spectrum?
  Connect to recent conjecture by Baggio and Sfondrini?
  Relation to low k results ?

  [Giribet+Hull+Kleban+Porrati+Rabinovici,Gaberdiel+Gopakumar]

- Fully backreacted geometries with non-zero moduli also known

Conclusions: Wrapping

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- Generalise to $\mathrm{AdS}_3 \times \mathrm{S}^3 \times \mathrm{T}^4$ backgrounds with other charges.

Thank you