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The omega-infinity limit of single spikes

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Abstract

A new infinite-size limit of strings in $\mathbb{R} \times \mathrm{S}^2$ is presented. The limit is obtained from single spike strings by letting the angular velocity parameter ω become infinite. We derive the energy-momenta relation of $\omega = \infty$ single spikes as their linear velocity $v \to 1$ and their angular momentum $\mathcal{J} \to 1$. Generally, the $v \to 1$, $\mathcal{J} \to 1$ limit of single spikes is singular and has to be excluded from the spectrum and be studied separately. We discover that the dispersion relation of omega-infinity single spikes contains logarithms in the limit $\mathcal{J} \to 1$. This result is somewhat surprising, since the logarithmic behavior in the string spectra is typically associated with their motion in non-compact spaces such as AdS. Omega-infinity single spikes seem to completely cover the surface of the 2-sphere they occupy, so that they may essentially be viewed as some sort of "brany strings". A proof of the sphere-filling property of omega-infinity single spikes is given in the appendix.

1. Introduction and motivation

The AdS/CFT correspondence has been revolutionized during the past ten years by the introduction of integrability methods [1,2] that can be used in order to solve the theories on both

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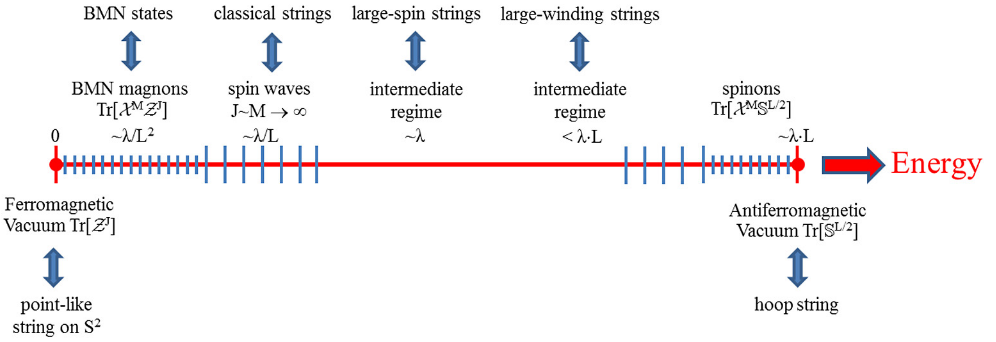

Fig. 1. Spectrum of AdS_5/CFT_4. Figure adapted from the talk in [6].

sides of the correspondence.[1] As far as a certain class of (long) rotating strings is concerned however,[2] integrability tools and techniques (such as the ABA, TBA, Y-system, QSC, etc.) have neither been sufficiently developed, nor do they provide the high-loop spectroscopic predictions that they typically yield at either weak coupling (e.g. 9-loop Konishi [3]) or at strong coupling and small spins (e.g. 3-loop Konishi [4]).[3] In this paper we will be dealing with the spectral problem in precisely one of those regimes (namely long strings in $\mathbb{R} \times S^2$) where the existing spectroscopic machinery is still too complicated to be used for explicit calculations of operator scaling dimensions and string-state energies.

A general description of the spectrum $E - L$ of planar AdS/CFT, based on the structure of the Heisenberg ferromagnet, can be found in the references [7] and [8] (see also Fig. 1). Let E denote the scaling dimension and L the length of the $\mathfrak{su}(2)$ operator.[4] We consider the thermodynamic limit $E, L \to \infty$. Qualitatively the spectrum is expected to be the same for greater values of the 't Hooft coupling λ. For the strongly coupled description of AdS/CFT, the generic structure of the string spectrum is also expected to be the same. The spectrum will also be similar in all the other sectors of AdS/CFT.

The bottom of the spectrum is occupied by the BPS operator $\text{Tr}\left[\mathcal{Z}^J\right]$ that is the vacuum state of a ferromagnetic spin chain with energy $E - J = 0$. The vacuum is dual to a point-like string that rotates at the equator of $S^2 \subset AdS_5 \times S^5$. Magnons are excitations above the ferromagnetic vacuum with energies $E - J \sim \lambda/J^2$ and large spins, $J \to \infty$. An M-magnon operator $\text{Tr}\left[\mathcal{X}^M \mathcal{Z}^J\right]$ $(L = J + M)$ is dual to a nearly point-like (BMN) string that rotates in $\mathbb{R} \times S^2$ with two angular momenta $J_1 = J \to \infty$ and $J_2 = M$ (finite).[5] For $J \sim M \to \infty$, we obtain a low-energy spin wave with $E - J \sim \lambda/J$. At the intermediate regime we find states with $E - J \sim \lambda$.

[1] In the large-N_c/planar limit ($N_c = \infty$) the string theory is essentially free ($g_s = \infty$) for $\lambda = 4\pi g_s N_c =$ const. AdS_5/CFT_4 is also thought to be quantum integrable in the planar limit.

[2] These are dual to long operators of $\mathcal{N} = 4$ super Yang–Mills (SYM) at strong 't Hooft coupling $\lambda \to \infty$.

[3] Even the more recently developed techniques, such as the quantum spectral curve method [5], succeed only when the coupling is weak and at strong coupling when the spin is small.

[4] In the following, $\mathcal{X}$, $\mathcal{Y}$, $\mathcal{Z}$ will denote the three complex scalar fields of $\mathcal{N} = 4$ SYM, composed out of the theory's six real scalars Φ. It was proven in [9] that the one-loop dilatation operator of the $\mathfrak{su}(2)$ sector of the theory (consisting of all the single-trace operators $\text{Tr}\left[\mathcal{Z}^J \mathcal{X}^M\right]$) is given by the Hamiltonian of the ferromagnetic $XXX_{1/2}$ Heisenberg spin chain.

[5] To get a BMN string [10] one more condition is needed, namely that the ratio N_c/J^2 must be held fixed.