3-point functions of universal scalars in maximal SCFTs at large $N$

by

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Abstract

We compute all 3-point functions of the “universal” scalar operators contained in the interacting, maximally supersymmetric CFTs at large $N$ by using the AdS/CFT correspondence. These SCFTs are related to the low energy description of M5, M2 and D3 branes, and the common set of universal scalars corresponds through the AdS/CFT relation to the fluctuations of the metric and the magnetic potential along the internal manifold. For the interacting $(0, 2)$ SCFT$_6$ at large $N$, which is related to M5 branes, this set of scalars is complete, while additional non-universal scalar operators are present in the $d = 4, \mathcal{N} = 4$ super Yang–Mills theory and in the $\mathcal{N} = 8$ SCFT$_3$, related to D3 and M2 branes, respectively.

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0. Introduction

The low energy dynamics of non-dilatonic superstring/M-theory branes identify an interesting class of interacting CFT possessing maximal supersymmetry [1]. These SCFT should presumably be given a description in terms of the collective coordinates of the branes. This is well known for a system of \( N \) coinciding D3 branes, whose collective degrees of freedom span the \( d = 4, \mathcal{N} = 4 \) \( U(N) \) super vector multiplet and whose infrared dynamics is described precisely by the corresponding super Yang–Mills theory [2]. A similar explicit description for a set of \( N \) coinciding M5 or M2 branes is unknown. Indeed, it is only known that the collective coordinates of a single M5 brane form a \( d = 6, \mathcal{N} = (0, 2) \) free tensor multiplet (a 2-form with selfdual field strength, 5 scalars and 2 Weyl fermions) [3,4] and that those of a single M2 brane form a \( d = 3, \mathcal{N} = 8 \) free scalar multiplet (8 bosons and 8 Majorana fermions) [5]. Interacting SCFTs describing the collective coordinates of \( N \) coinciding M5 or M2 branes remain instead quite mysterious. However, superstring/M-theory predicts the existence of these models [6–8] and, in fact, suggests a full ADE classification. A concrete handle on the problem is provided by the AdS/CFT duality conjecture, which relates these SCFT in \( d = 3, 4, 6 \) to superstring/M-theory on \( \text{AdS}_{4,5,7} \times S_{7,5,4} \) [9–11]. Specifically, at large \( N \), one can approximate the superstring/M-theory by the corresponding classical supergravity. Then, the latter may be used to obtain informations on the strong coupling limit of the related interacting SCFTs and, in the case of SCFT_{3,6}, also to get important clues about their mysterious lagrangian formulation. The AdS/CFT duality conjecture has been tested extensively in the literature (see ref. [12] and references therein) and used to compute 3- and 4-point functions of some chiral operators (a partial list consists of refs. [13–24]).

In this paper, we continue our analysis of the AdS/CFT correspondence presented in [22–24], and address the problem of computing the 3 point functions for a set of scalar operators which are present in all of the above mentioned theories at large \( N \). In fact, there are three families of such scalars, to be denoted by \( \mathcal{O}^s, \mathcal{O}^f, \mathcal{O}^t \), which are in correspondence with the metric and the magnetic potential fluctuations along the internal manifold (the metric contributing with two Kaluza-Klein families due to its splitting into a trace and a traceless part). They form a kind of “universal” scalar sector common to all the non-dilatonic branes, which is reminiscent of the NS-NS universal sector present in the spectrum of the various closed superstrings. At large \( N \), all but a finite number of the supersymmetric short multiplets contain precisely one scalar \( \mathcal{O}^s, \mathcal{O}^f, \mathcal{O}^t \), with \( \mathcal{O}^s \) being the chiral primary. Their conformal dimensions are given by

\[
\Delta^s = \Delta, \quad \Delta^f = \Delta + 2, \quad \Delta^t = \Delta + 4,
\]  

(0.1)
where

$$\Delta = \frac{n + 1}{D - n - 3} k,$$

(0.2)

$n$ is the dimension of the brane, $D$ is the space time dimension and $k \geq 4$ is an integer characterizing the multiplet. The exceptional multiplets, corresponding to the values $k = 2, 3$, do not contain the operator $\mathcal{O}^i$. For the M5 brane case, this set of scalars is complete at large $N$, as all other operators have a non trivial tensorial character. On the other hand, for the M2 and D3 branes, additional non-universal scalars are present in the spectrum (see, e.g. the tables in [25, 26]).

The simultaneous treatment of the universal sector is made possible by the use of the general gravitational model introduced in [23], which was shown later in [24] to correctly reproduce the universal scalar self couplings also in the case of the dyonic D3 brane (where the full lagrangian of type IIB supergravity contains a 4-form with selfdual field strength).

Thus, in the following, we briefly review our general gravitational model and present the result for all of the 3-point couplings of the universal scalars. As a check, we have carried out the computation in two independent ways, by expanding the action at the cubic order in the scalar fields and by studying the quadratic corrections to the scalar equations of motion. Of course, we obtained the same final result. Then, the application of AdS/CFT duality allows us to obtain the announced universal scalar 3-point functions. We tried to cast the resulting expressions in a way which may suggest a group theoretic interpretation. Finally, we present some technical details on tensor spherical harmonics and their integrals in an appendix.

1. Identification of the universal scalar sector

According to the AdS/CFT duality principles [9–11], the low energy world volume CFT of $N$ coincident M5, M2, D3 branes at large $N$ is described by $D = 11$, $D = 11$, $D = 10$ type IIB classical supergravity compactified on $\text{AdS}_7 \times S_4$, $\text{AdS}_4 \times S_7$, $\text{AdS}_5 \times S_5$, respectively. The CFT scalar fields, whose three point functions we want to compute, are related by duality in a precise way to certain fluctuations of the AdS bosonic supergravity fields around a maximally supersymmetric Freund–Rubin background [27]. In ref. [23, 24], it has been shown that the dynamics of these fluctuations up to third order is governed by a gravitational action that has the same form for all the three types of branes mentioned above and is, therefore, universal. Let us describe and justify the model briefly.

Space time $M_D$ is $\text{AdS}_{D-2-p} \times S_{2+p}$. The relevant fields are the metric $g$ and the $1+p$ form field $A_{1+p}$ with field strength $F_{2+p} = dA_{1+p}$. The Freund–Rubin background

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1 We denote form degree on $M_D$ by a suffix, e. g. $\omega_r$ is a $r$ form on $M_D$.  

3
\( \tilde{g}, \tilde{A}_{1+p} \) is such that \( \tilde{g} \) is factorized and \( \tilde{F}_{2+p} = \tilde{F}_{(0,2+p)} \). The relevant bosonic fluctuations of \( g \) and \( A_{1+p} \) around the background are such that \( g \) remains factorized and \( F_{2+p} = F_{(0,2+p)} + da_{(0,1+p)} \) \(^2\). The action is given by

\[
I = \frac{1}{4\kappa^2} \int_{\text{AdS}_{D-2-p} \times S_{2+p}} [R(g) *_g 1 - F_{2+p} \wedge *_g F_{2+p}],
\]

\( g = g' \oplus g'' \), \( F_{2+p} = \tilde{F}_{(0,2+p)} + da_{(0,1+p)} \). \( (1.1) \)

The important cases are those for which \((D,p) = (11,2), (11,5), (10,3)\).

For the M5 theory \(((D,p) = (11,2))\), the above action is obtained directly from that of the bosonic sector of \( D = 11 \) supergravity by noting that, for the fluctuation considered here, the Chern–Simons term vanishes identically.

For the M2 theory \(((D,p) = (11,5))\), the situation is slightly more complicated. Using the standard 3–form formulation of \( D = 11 \) supergravity is inconvenient as the relevant scalar fluctuation contained in the fluctuation \( a_{(3,0)} \) of \( A_3 \) comes about as the solution of the constraint

\[
d * \tilde{g}' a_{(3,0)} = 0
\]

\( (1.3) \)

entailed by gauge fixing at quadratic level, which is difficult to implement in an off–shell fashion. This problem can be solved by means of a standard dualization trick, whereby the 3–form \( A_3 \) is replaced by a 6–form \( A_6 \) such that \( F_7 = *_g F_4 \). Since the Chern–Simons term vanishes also in this case for the fluctuation considered here, the resulting action takes the simple form \((1.1)\). However, in the dual formulation, the relevant scalar fluctuation is contained in the fluctuation \( a_{(0,6)} \) of \( A_6 \) and can thus be treated in an off–shell fashion in a way completely analogous to that of the M5 brane.

For the D3 theory \(((D,p) = (10,3))\), the relevant fields are the metric \( g \) and the IIB Ramond–Ramond 4 form field \( A_4 \) with selfdual field strength \( F_5^{sd} = dA_4 \)

\[
F_5^{sd} = *_g F_5^{sd}.
\]

\( (1.4) \)

The selfdual Freund–Rubin background \( \tilde{g}, \tilde{A}_4 \) is such that \( \tilde{g} \) is factorized and \( \tilde{F}_5^{sd} = 2^{-\frac{1}{2}} (\tilde{F}_{(0,5)} + *_{\tilde{g}} \tilde{F}_{(0,5)}) \). The relevant fluctuations of \( g \) and \( A_4 \) around the background are

\(^2\) We say that a metric \( g \) on \( M_D \) is factorized if \( g \) has the block structure \( g = g' \oplus g'' \), where \( g', g'' \) are metrics on \( \text{AdS}_{D-2-p}, S_{2+p} \), respectively. Similarly, we denote form degree on the factors \( \text{AdS}_{D-2-p}, S_{2+p} \) by a pair of suffixes, e. g. \( \omega_{(r,s)} \) denotes a \( r + s \) form on \( M_D \) that is a \( r \) form on \( \text{AdS}_{D-2-p} \) and a \( s \) form on \( S_{2+p} \).
such that \( g \) is factorized, as usual, and \( F_{5}^{sd} = \tilde{F}_{5}^{sd} + da_{4} \), where \( a_{4} = 2^{-\frac{1}{2}}(a_{(4,0)} + a_{(0,4)}) \). The selfduality equations (1.4) relate the fluctuations \( a_{(4,0)}, a_{(0,4)} \) and allow in principle to express \( a_{(4,0)} \) in terms of \( a_{(0,4)} \). Upon doing this, the resulting field equations can be seen to be equivalent to those obtained from the action (1.1).

The standard AdS\(_{D-2-p} \times S_{2+p} \) Freund Rubin solution \( \bar{g}_{ij}, \bar{A}_{i_{1} \cdots i_{1+p}} \) of the field equations following from the action (1.1) is given by

\[
\bar{R}_{\kappa\lambda\mu\nu} = -a^{2}(\bar{g}_{\kappa\mu}\bar{g}_{\lambda\nu} - \bar{g}_{\kappa\nu}\bar{g}_{\lambda\mu}), \quad a^{2} = \frac{(1 + p)}{(D - 2)(D - 3 - p)} \epsilon^{2}, \quad (1.5a)
\]

\[
\bar{R}_{\alpha\beta\gamma\delta} = \bar{\epsilon}^{2}(\bar{g}_{\alpha\gamma}\bar{g}_{\beta\delta} - \bar{g}_{\alpha\delta}\bar{g}_{\beta\gamma}), \quad \bar{\epsilon}^{2} = \frac{(D - 3 - p)}{(D - 2)(1 + p)} \epsilon^{2}, \quad (1.5b)
\]

\[
\bar{F}_{\alpha_{1} \cdots \alpha_{2+p}} = \epsilon \bar{e}_{\alpha_{1} \cdots \alpha_{2+p}}, \quad (1.6)
\]

where \( \bar{\epsilon}_{\alpha_{1} \cdots \alpha_{2+p}} \) denotes the standard volume form on the unit sphere and \( \epsilon \) is an arbitrary mass scale parameterizing the compactification \(^3\). The other components of the Riemann tensor and the field strength vanish identically.

We expand the action in fluctuations around the background \( \bar{g}_{ij}, \bar{A}_{i_{1} \cdots i_{1+p}} \). We parameterize the fluctuations \( \delta g_{ij}, \delta A_{i_{1} \cdots i_{1+p}} \) of the fields \( g_{ij}, A_{i_{1} \cdots i_{1+p}} \) around the background as in [28]

\[
\delta g_{\alpha\beta} = f_{\alpha\beta} + \nabla_{\alpha}n_{\beta} + \nabla_{\beta}n_{\alpha} + (\nabla_{\alpha}\nabla_{\beta} - \frac{1}{2+p}\bar{g}_{\alpha\beta}\nabla_{\gamma}\nabla_{\gamma})q + \frac{1}{2+p}\bar{g}_{\alpha\beta}p,
\]

\[
f^{\gamma\gamma} = 0, \quad \nabla^{\gamma}f_{\gamma\alpha} = 0, \quad \nabla^{\gamma}n_{\gamma} = 0, \quad (1.7)
\]

\[
\delta A_{\alpha_{1} \cdots \alpha_{1+p}} = (1 + p)\nabla_{[\alpha_{1}}a_{\alpha_{2} \cdots \alpha_{1+p}]} + \bar{\epsilon}_{\alpha_{1} \cdots \alpha_{1+p}}^{\gamma}\nabla_{\gamma}b, \quad \nabla_{\gamma}a_{\gamma\alpha_{3} \cdots \alpha_{1+p}} = 0. \quad (1.8)
\]

Fluctuations of the other components of \( g_{ij} \) and \( A_{i_{1} \cdots i_{1+p}} \) can be disregarded as they are independent up to third order from the ones we are interested in and therefore do not contribute to the relevant scalar 3-point couplings.

The gauge can be partially fixed by eliminating those gauge invariances which do not correspond to the usual reparameterization and form gauge invariances from the AdS\(_{D-2-p} \) perspective. This can be done by imposing

\[
\nabla^{\beta}(\delta g_{\beta\alpha} - \frac{1}{2+p}\bar{g}_{\beta\alpha}\delta g^{\gamma}_{\gamma}) = 0, \quad (1.9)
\]

\(^3\) In this paper, we adopt the following conventions. Latin lower case letters \( i, j, k, l, \ldots \) denote \( M_{D} \) indices. Late Greek lower case letters \( \kappa, \lambda, \mu, \nu, \ldots \) denote AdS\(_{D-2-p} \) indices. Early Greek lower case letters \( \alpha, \beta, \gamma, \delta, \ldots \) denote \( S_{2+p} \) indices.
as shown in [28]. Fixing the gauge entails a number of constraints which must be disposed of as explained in [24].

There are three universal families of $\text{AdS}_{D-2-p}$ scalar fields contained in the fluctuations listed above, which we denote as $f_I$, $s_I$, $t_I$. The scalar fields $f_I$ are defined by expanding $f_{\alpha\beta}$ (cfr. eq. (1.7)) with respect to an orthonormal basis $\{Y_I^{(2)}\}$ of symmetric traceless transversal 2–tensor spherical harmonics of $S_{2+p}$ (cfr. appendix A1)

$$f_{\alpha\beta} = \sum_I f_I Y_I^{(2)}_{\alpha\beta}.$$  \hspace{1cm} (1.11)

The scalar fields $s_I$, $t_I$ are given by linear functionals of $\pi$, $b$ (cfr. eq. (1.7), (1.8)) non local in $S_{2+p}$ defined as follows. One expands the scalar fields $\pi$, $b$ with respect to an orthonormal basis $\{Y_I^{(0)}\}$ of scalar spherical harmonics of $S_{2+p}$ (cfr. appendix A1)

$$\pi = \sum_I \pi_I Y_I^{(0)}, \quad b = \sum_I b_I Y_I^{(0)}$$  \hspace{1cm} (1.12a), (1.12b)

and identifies the scalar mass eigenstates as given by [23, 24]

$$s_I = \frac{1}{2k+1+p}\left(\frac{1}{2(2+p)(D-3-p)}\pi_I + \frac{(-1)^p(k+1+p)}{(1+p)(D-2)} eb_I\right),$$  \hspace{1cm} (1.13a)

$$t_I = \frac{1}{2k+1+p}\left(\frac{1}{2(2+p)(D-3-p)}\pi_I - \frac{(-1)^p k}{(1+p)(D-2)} eb_I\right).$$  \hspace{1cm} (1.13b)

It should be kept in mind that the range of the quantum numbers $I$ of $f_I$ differs from that of the quantum numbers $I$ of $s_I$, $t_I$, as these ranges parameterize orthogonal bases of spherical harmonics of different tensorial rank. However, we shall use the same notation for these different quantum numbers for simplicity, as no confusion is possible.

2. The cubic action of the universal scalar sector

From the action (1.1), one can extract the couplings of the scalars $f_I$, $s_I$ and $t_I$ defined in the previous section. After performing some field redefinitions, one finds that their action to cubic order is given by

$$I_{\text{cubic}}^{f_{\text{st}}} = \frac{1}{4\kappa^2} \int_{\text{AdS}_{d+1}} d^{d+1} y (-\bar{g}_{d+1})^{\frac{1}{2}} \left[ \frac{1}{2} \sum_i A_i \psi_i (\Box - m_i^2) \psi_i + \frac{1}{2} \sum_{ijk} G_{ijk} \psi_i \psi_j \psi_k \right],$$  \hspace{1cm} (2.1)
where $d = D - 3 - p$, $\Box$ denotes the d’Alembertian on AdS$_{d+1}$ and the index $i = \{I, a\}$ contains a flavor index $a$ for the $(f, s, t)$ types of fields, i.e. $\psi_i = \psi_i^a = (f_I, s_I, t_I)$. The various constants appearing in the actions are given by the following expressions.

\begin{align}
A_i^f &= \frac{1}{2} z_I e^{-2-p}, \\
A_i^s &= \frac{2\nu k(k - 1)(2k + 1 + p)}{k + \gamma_s} z_I e^{-2-p}, \\
A_i^t &= \frac{2\nu(k + 1 + p)(k + 2 + p)(2k + 1 + p)}{k + \gamma_t} z_I e^{-2-p};
\end{align}

\begin{align}
m_{i}^{f2} &= k(k + 1 + p)e^{2}, \\
m_{i}^{s2} &= k(k - 1 - p)e^{2}, \\
m_{i}^{t2} &= (k + 1 + p)(k + 2 + 2p)e^{2};
\end{align}

\begin{align}
G_{I_1 I_2 I_3}^{fff} &= (\alpha + \frac{1}{2}(1 + p)) a_{I_1 I_2 I_3} \langle T_{I_1} T_{I_2} T_{I_3} \rangle e^{-p}, \\
G_{I_1 I_2 I_3}^{fss} &= 4(D - 2) \frac{\alpha_1 \alpha_2 (\alpha + \frac{1}{2}(1 + p))(\alpha + \frac{1}{2}(1 + p))}{k_3 + \gamma_s} a_{I_1 I_2 I_3} \langle T_{I_1} T_{I_2} C_{I_3} \rangle e^{-p}, \\
G_{I_1 I_2 I_3}^{fft} &= 4(D - 2) \frac{(\alpha + \frac{1}{2}(1 + p)) (\alpha + \frac{1}{2}(1 + p)) \alpha_3 (\alpha + 1 + p)}{k_3 + \gamma_t} a_{I_1 I_2 I_3} \langle T_{I_1} T_{I_2} C_{I_3} \rangle e^{-p}, \\
G_{I_1 I_2 I_3}^{sss} &= 8\nu \frac{\alpha_1 (\alpha - \frac{1}{2}(1 + p)) (\alpha + \frac{1}{2}(1 + p))}{(k_2 + \gamma_t)(k_3 + \gamma_s)} \\
&\quad \times \left\{ \left( \alpha - 1 \right) \left( \alpha + \frac{1 + p}{D - 3 - p} \right) + \frac{\theta}{\nu} F^{fss} \right\} a_{I_1 I_2 I_3} \langle T_{I_1} C_{I_2} C_{I_3} \rangle e^{-p}, \\
G_{I_1 I_2 I_3}^{fft} &= 8\nu \frac{\alpha_1 (\alpha + 1 + p) (\alpha + \frac{1}{2}(1 + p)) (\alpha + \frac{1}{2}(1 + p))}{(k_2 + \gamma_t)(k_3 + \gamma_t)} \\
&\quad \times \left\{ \left( \alpha + 1 + p \right) \frac{(D - 4 - p)}{D - 3 - p} \left( \alpha + p + 2 \right) + \frac{\theta}{\nu} F^{fft} \right\} a_{I_1 I_2 I_3} \langle T_{I_1} C_{I_2} C_{I_3} \rangle e^{-p}, \\
G_{I_1 I_2 I_3}^{fst} &= 8\nu \frac{\alpha_1 \alpha_2 + 1 + p) (\alpha + \frac{1}{2}(1 + p)) (\alpha + \frac{1}{2}(1 + p))}{(k_2 + \gamma_s)(k_3 + \gamma_t)} \\
&\quad \times \left\{ \left( \alpha + \frac{1 + p}{D - 3 - p} \right) \left( \alpha - 1 \right) + \frac{\theta}{\nu} F^{fss} \right\} a_{I_1 I_2 I_3} \langle T_{I_1} C_{I_2} C_{I_3} \rangle e^{-p}, \\
G_{I_1 I_2 I_3}^{sss} &= 32(D - 2)\nu \frac{\alpha_1 \alpha_2 \alpha_3 (\alpha - \frac{1}{2}(1 + p)) (\alpha + \frac{1}{2}(1 + p))}{(k_1 + \gamma_s)(k_2 + \gamma_s)(k_3 + \gamma_s)}
\end{align}
where we have defined for notational convenience

\begin{align}
\nu &= (D - 2)(1 + p)(D - 3 - p), \\
\gamma_s &= \frac{1 + p}{D - 3 - p}, \quad \gamma_t = \frac{(1 + p)(D - 4 - p)}{D - 3 - p}, \\
\theta &= (1 + p)(D - 3 - p) - 2(D - 2),
\end{align}

\(\bar{e}^2\) is defined in eq. (1.5b), while \(\alpha_1,\alpha_2,\alpha_3,\alpha, z_l, a_{l_1l_2l_3}\) and the contractions \(\langle TTT \rangle, \langle T^2C \rangle, \langle TC \rangle, \langle CC \rangle\) are defined in appendix A1. Note that the auxiliary functions \(F^{fss}, F^{fft}, \ldots\) appearing in the couplings are always multiplied by \(\theta\) and do not contribute to the relevant cases of AdS\(_{5,7,4}\times S_{5,4,7}\) where \(\theta\) vanishes. The explicit expressions for such functions, which may be needed in future applications, are listed in appendix A2.

Writing above

\begin{align}
A_I &= \bar{A}_I z_l \bar{e}^{-2-p}, \\
m_I^2 &= \bar{m}_I^2 \bar{e}^2,
\end{align}

\(G_{l_1l_2l_3} = \bar{G}_{l_1l_2l_3} a_{l_1l_2l_3} \langle Y_{l_1} Y_{l_2} Y_{l_3} \rangle \bar{e}^{-p},\)

where the \(\langle Y_{l_1} Y_{l_2} Y_{l_3} \rangle\) denotes the appropriate tensor/scalar harmonic contractions, we get the following expressions.
\[ \mathcal{G}_{I_1 I_2 I_3} = \alpha + \frac{3}{2}, \]

\[ \bar{G}_{I_1 I_2 I_3} = \frac{2^3 3^2 \alpha_1 \alpha_2 (\alpha_3 + \frac{3}{2})(\alpha + \frac{3}{2})}{k_3 + \frac{1}{2}}, \]

\[ G_{I_1 I_2 I_3} = \frac{2^3 3^2 (\alpha_1 + \frac{3}{2})(\alpha_2 + \frac{3}{2}) \alpha_3 (\alpha + 3)}{k_3 + \frac{5}{2}}, \]

\[ \bar{G}_{I_1 I_2 I_3} = \frac{2^4 3^4 (\alpha_1 - \frac{3}{2})(\alpha_1 - 1) \alpha_1 \alpha (\alpha + \frac{1}{2})(\alpha + \frac{3}{2})}{(k_2 + \frac{1}{2})(k_3 + \frac{1}{2})}, \]

\[ G_{I_1 I_2 I_3} = \frac{2^4 3^4 \alpha_1 (\alpha_1 + \frac{5}{2})(\alpha_1 + 3)(\alpha + \frac{3}{2})(\alpha + 4)(\alpha + \frac{9}{2})}{(k_2 + \frac{5}{2})(k_3 + \frac{1}{2})}, \]

\[ \bar{G}_{I_1 I_2 I_3} = \frac{2^4 3^4 \alpha_1 (\alpha_2 + \frac{5}{2})(\alpha_2 + 3)(\alpha_3 - 1)(\alpha_3 - \frac{3}{2})(\alpha + \frac{3}{2})}{(k_2 + \frac{1}{2})(k_3 + \frac{5}{2})}, \]

\[ G_{I_1 I_2 I_3} = \frac{2^6 3^6 \alpha_1 \alpha_2 \alpha_3 (\alpha - 1)(\alpha^2 - \frac{1}{4})(\alpha^2 - \frac{9}{4})}{(k_1 + \frac{1}{2})(k_2 + \frac{1}{2})(k_3 + \frac{1}{2})}, \]

\[ \bar{G}_{I_1 I_2 I_3} = \frac{2^6 3^6 (\alpha_1 + \frac{3}{2})(\alpha_2 + \frac{3}{2}) \alpha_3 (\alpha_3 - 1)(\alpha_3 - 2)(\alpha_3 - \frac{5}{2})(\alpha_3 - 3)(\alpha + \frac{3}{2})}{(k_1 + \frac{5}{2})(k_2 + \frac{1}{2})(k_3 + \frac{5}{2})}, \]

\[ G_{I_1 I_2 I_3} = \frac{2^6 3^6 \alpha_1 \alpha_2 (\alpha_3 + \frac{3}{2})(\alpha_3 + \frac{5}{2})(\alpha_3 + 4)(\alpha_3 + \frac{9}{2})(\alpha + 3)}{(k_1 + \frac{5}{2})(k_2 + \frac{5}{2})(k_3 + \frac{1}{2})}, \]

\[ \bar{G}_{I_1 I_2 I_3} = \frac{2^6 3^6 (\alpha_1 + \frac{3}{2})(\alpha_2 + \frac{3}{2})(\alpha_3 + \frac{3}{2})(\alpha + 3)(\alpha + 4)(\alpha + 5)(\alpha + \frac{11}{2})(\alpha + 6)}{(k_1 + \frac{5}{2})(k_2 + \frac{5}{2})(k_3 + \frac{5}{2})}. \]
\[ \text{AdS}_4 \times S_7 \]

\[ \bar{A}_f^I = \frac{1}{2}, \quad (2.12a) \]
\[ \bar{A}_s^I = \frac{2^2 3^4 k (k - 1)(2k + 6)}{k + 2}, \quad (2.12b) \]
\[ \bar{A}_t^I = \frac{2^2 3^4 (k + 6)(k + 7)(2k + 6)}{k + 4}, \quad (2.12c) \]

\[ \bar{m}_f^{I2} = k(k + 6), \quad (2.13a) \]
\[ \bar{m}_s^{I2} = k(k - 6), \quad (2.13b) \]
\[ \bar{m}_t^{I2} = (k + 6)(k + 12); \quad (2.13c) \]

\[ \bar{G}_{fff}^{I_1 I_2 I_3} = \alpha + 3, \quad (2.14a) \]
\[ \bar{G}_{fss}^{I_1 I_2 I_3} = \frac{2^2 3^2 \alpha_1 \alpha_2 (\alpha_3 + 3)(\alpha + 3)}{k_3 + 2}, \quad (2.14b) \]
\[ \bar{G}_{fft}^{I_1 I_2 I_3} = \frac{2^2 3^2 (\alpha_1 + 3)(\alpha_2 + 3)\alpha_3 (\alpha + 6)}{k_3 + 4}, \quad (2.14c) \]
\[ \bar{G}_{fss}^{I_1 I_2 I_3} = \frac{2^4 3^4 (\alpha_1 - 3)(\alpha_1 - 1)\alpha_1 \alpha (\alpha + 2)(\alpha + 3)}{(k_2 + 2)(k_3 + 2)}, \quad (2.14d) \]
\[ \bar{G}_{ftt}^{I_1 I_2 I_3} = \frac{2^4 3^4 \alpha_1 (\alpha_1 + 4)(\alpha_1 + 6)(\alpha + 3)(\alpha + 7)(\alpha + 9)}{(k_2 + 2)(k_3 + 4)}, \quad (2.14e) \]
\[ \bar{G}_{fss}^{I_1 I_2 I_3} = \frac{2^4 3^4 \alpha_1 (\alpha_2 + 4)(\alpha_2 + 6)(\alpha_3 - 3)(\alpha_3 - 1)(\alpha + 3)}{(k_2 + 2)(k_3 + 4)}, \quad (2.14f) \]
\[ \bar{G}_{sss}^{I_1 I_2 I_3} = \frac{2^6 3^6 \alpha_1 \alpha_2 \alpha_3 (\alpha + 2)(\alpha^2 - 1)(\alpha^2 - 9)}{(k_1 + 2)(k_2 + 2)(k_3 + 2)}, \quad (2.14g) \]
\[ \bar{G}_{sst}^{I_1 I_2 I_3} = \frac{2^6 3^6 (\alpha_1 + 3)(\alpha_2 + 3)\alpha_3 (\alpha_3 - 1)(\alpha_3 - 2)(\alpha_3 - 4)(\alpha_3 - 6)(\alpha + 3)}{(k_1 + 2)(k_2 + 2)(k_3 + 4)}, \quad (2.14h) \]
\[ \bar{G}_{ttt}^{I_1 I_2 I_3} = \frac{2^6 3^6 \alpha_1 \alpha_2 (\alpha_3 + 3)(\alpha_3 + 4)(\alpha_3 + 5)(\alpha_3 + 7)(\alpha_3 + 9)(\alpha + 6)}{(k_1 + 4)(k_2 + 4)(k_3 + 4)}, \quad (2.14i) \]
\[ \bar{G}_{ttt}^{I_1 I_2 I_3} = \frac{2^6 3^6 (\alpha_1 + 3)(\alpha_2 + 3)(\alpha + 6)(\alpha + 7)(\alpha + 8)(\alpha + 10)(\alpha + 12)}{(k_1 + 4)(k_2 + 4)(k_3 + 4)}. \quad (2.14j) \]
$\text{AdS}_5 \times S_5$

\[ \bar{A}_f^f = \frac{1}{2}, \]  
\[ \bar{A}_s^s = \frac{2^8k(k - 1)(2k + 4)}{k + 1}, \]  
\[ \bar{A}_t^t = \frac{2^8(k + 4)(k + 5)(2k + 4)}{k + 3}; \]  
\[ \bar{m}_f^f = k(k + 4), \]  
\[ \bar{m}_s^s = k(k - 4), \]  
\[ \bar{m}_t^t = (k + 4)(k + 8); \]

\[ \bar{G}_{1123}^{fff} = \alpha + 2, \]  
\[ \bar{G}_{1123}^{ffs} = \frac{2^5\alpha_1\alpha_2(\alpha_3 + 2)(\alpha + 2)}{k_3 + 1}, \]  
\[ \bar{G}_{1123}^{fft} = \frac{2^5(\alpha_1 + 2)(\alpha_2 + 2)\alpha_3(\alpha + 4)}{k_3 + 3}, \]  
\[ \bar{G}_{1123}^{ss} = \frac{2^{10}(\alpha_1 - 2)(\alpha_1 - 1)\alpha_1\alpha(\alpha + 1)(\alpha + 2)}{(k_2 + 1)(k_3 + 1)}, \]  
\[ \bar{G}_{1123}^{tt} = \frac{2^{10}\alpha_1(\alpha_1 + 3)(\alpha_1 + 4)(\alpha + 2)(\alpha + 5)(\alpha + 6)}{(k_2 + 3)(k_3 + 3)}, \]  
\[ \bar{G}_{1123}^{fst} = \frac{2^{10}\alpha_1(\alpha_2 + 3)(\alpha_2 + 4)(\alpha_3 - 2)(\alpha_3 - 1)(\alpha + 2)}{(k_2 + 1)(k_3 + 3)}, \]  
\[ \bar{G}_{1123}^{sss} = \frac{2^{15}\alpha_1\alpha_2\alpha_3(\alpha^2 - 1)(\alpha^2 - 4)}{(k_1 + 1)(k_2 + 1)(k_3 + 1)}, \]  
\[ \bar{G}_{1123}^{sst} = \frac{2^{15}(\alpha_1 + 2)(\alpha_2 + 2)\alpha_3(\alpha_3 - 1)(\alpha_3 - 2)(\alpha_3 - 3)(\alpha_3 - 4)(\alpha + 2)}{(k_1 + 1)(k_2 + 1)(k_3 + 3)}, \]  
\[ \bar{G}_{1123}^{tts} = \frac{2^{15}\alpha_1\alpha_2(\alpha_3 + 3)(\alpha_3 + 4)(\alpha_3 + 5)(\alpha_3 + 6)(\alpha + 4)}{(k_1 + 3)(k_2 + 3)(k_3 + 1)}, \]  
\[ \bar{G}_{1123}^{ttt} = \frac{2^{15}(\alpha_1 + 2)(\alpha_2 + 2)(\alpha_3 + 2)(\alpha + 4)(\alpha + 5)(\alpha + 6)(\alpha + 7)(\alpha + 8)}{(k_1 + 3)(k_2 + 3)(k_3 + 3)}. \]
3. Computation of the 3 point functions of the universal scalar sector

We are now ready to compute two and three point functions in the SCFTs using the AdS\(_{d+1}/CFT_d\) correspondence. The general formulas derived in [29,30] work with AdS radius set to 1. Assume that the AdS scalar fields \(\phi_i\) correspond to the CFT local field \(O_i\). The mass \(m_i\) of \(\psi_i\) and the conformal dimension \(\Delta_i\) of \(O_i\) are related as

\[
\Delta_i = \frac{1}{2} \left[ d + \left( d^2 + 4m_i^2 \right)^{\frac{1}{2}} \right]. \tag{3.1}
\]

Then

\[
\langle O_i(x)O_j(y) \rangle = \frac{A_i}{4\kappa^2 \pi^{\frac{d}{2}}} \frac{2}{\Delta_i} \frac{\Delta_i - \frac{d}{2}}{\Gamma(\Delta_i - \frac{d}{2})} \frac{\Gamma(\Delta_i + 1)}{\Gamma(\Delta_i - \frac{d}{2})} \left( w_i \right)^2 \delta_{ij} |x - y|^{2\Delta_i}, \tag{3.2}
\]

where \(\frac{A_i}{4\kappa^2}\) is the coefficient of the canonically normalized kinetic term of the bulk field \(\psi_i\) as in eq. (2.1) and

\[
\langle O_i(x)O_j(y)O_k(z) \rangle = \frac{R_{ijk}}{|x - y|^{\Delta_i + \Delta_j - \Delta_k} |y - z|^{\Delta_j + \Delta_k - \Delta_i} |z - x|^{\Delta_k + \Delta_i - \Delta_j}}, \tag{3.3}
\]

with

\[
R_{ijk} = \frac{G_{ijk} 1}{4\kappa^2 2\pi^d} \frac{\Gamma\left(\frac{1}{2}(\Delta_i + \Delta_j - \Delta_k)\right) \Gamma\left(\frac{1}{2}(\Delta_j + \Delta_k - \Delta_i)\right) \Gamma\left(\frac{1}{2}(\Delta_k + \Delta_i - \Delta_j)\right)}{\Gamma\left(\Delta_i - \frac{d}{2}\right) \Gamma\left(\Delta_j - \frac{d}{2}\right) \Gamma\left(\Delta_k - \frac{d}{2}\right)} w_i w_j w_k, \tag{3.4}
\]

where \(\frac{G_{ijk}}{4\kappa^2}\) is the cubic coupling constant of \(\psi_i, \psi_j, \psi_k\) as in eq. (2.1). The factors \(w_i\) parameterize unknown proportionality constants which relate the fields \(\psi_i\) to the sources of the operators \(O_i\), namely the generating functional of correlators reads as \(\langle e^\int w_i \psi_i O_i \rangle_{\text{SCFT}}\). For the present purposes we follow ref. [13] and fix them to normalize the two point functions as

\[
\langle O_i(x)O_j(y) \rangle = \frac{\delta_{ij}}{|x - y|^{2\Delta_i}}. \tag{3.5}
\]

With this canonical normalization the three point functions are readily computed.

In our case, \(d = D - 3 - p\). Imposing that the AdS radius is 1 fixes the value of \(\bar{e}\) to be

\[
\bar{e} = \frac{d}{1+p}. \tag{3.6}
\]

We denote by \(O_f^I, O_s^I, O_t^I\) the CFT\(_d\) operators corresponding to the AdS\(_{d+1}\) scalars \(f_I, s_I, t_I\) in the AdS\(_{d+1}/CFT_d\) duality. Their dimensions are given by

\[
\Delta_f^I = \frac{d(k+1+p)}{1+p}, \tag{3.7a}
\]

\[
\Delta_s^I = \frac{dk}{1+p}, \tag{3.7b}
\]

\[
\Delta_t^I = \frac{d(k+2+2p)}{1+p}. \tag{3.7c}
\]
Separating out the group theory factors in the $R_{ijk}$ coefficients by defining

$$ R_{ijk} = \bar{R}_{ijk} \langle \mathcal{Y}_{I_1} \mathcal{Y}_{I_2} \mathcal{Y}_{I_3} \rangle $$

as in eq. (2.8), we find the following expressions.

**AdS$_7 \times S_4$**

In this case one has $\frac{1}{4\kappa^2} = \frac{2N^3}{\pi^5}$ and $\bar{e} = 2$. One has

$$ \Delta^f_I = 2k + 6, $$

$$ \Delta^s_I = 2k, $$

$$ \Delta^t_I = 2k + 12. $$

Set

$$ \phi(k) = 4 \left[ \frac{(2k + 1)!}{(2k + 2)! (2k + 5)!} \right]^{\frac{1}{2}}, $$

$$ \sigma(k) = \left[ (2k - 2)! \right]^{-\frac{1}{2}}, $$

$$ \tau(k) = 16 \left[ \frac{(2k + 1)!(2k + 4)!(2k + 7)!}{(2k + 6)!(2k + 8)!(2k + 9)!(2k + 11)!} \right]^{\frac{1}{2}}. $$

Then,

$$ R_{i_1 i_2 i_3}^{fff} = \frac{2}{4(\pi N)^{\frac{3}{2}}} \phi(k_1) \phi(k_2) \phi(k_3) 2^{2\alpha} \frac{\Gamma(2\alpha + 4)\Gamma(2\alpha + 6)}{\Gamma(2\alpha + 3)\Gamma(2\alpha + 5)} \Gamma(\alpha + 3) $$

$$ \times \frac{\Gamma(2\alpha + 3)\Gamma(2\alpha + 3)\Gamma(2\alpha + 3)}{\Gamma(2\alpha + 2)\Gamma(2\alpha + 2)\Gamma(2\alpha + 2)} \Gamma(\alpha_1 + \frac{3}{2}) \Gamma(\alpha_2 + \frac{3}{2}) \Gamma(\alpha_3 + \frac{3}{2}), $$

$$ R_{i_1 i_2 i_3}^{ffs} = \frac{1}{4(\pi N)^{\frac{3}{2}}} \phi(k_1) \phi(k_2) \sigma(k_3) 2^{2\alpha} \Gamma(\alpha + 2) $$

$$ \times \frac{\Gamma(2\alpha + 6)}{\Gamma(2\alpha + 2)} \Gamma(\alpha_1 + \frac{1}{2}) \Gamma(\alpha_2 + \frac{1}{2}) \Gamma(\alpha_3 + \frac{5}{2}), $$

$$ R_{i_1 i_2 i_3}^{fft} = \frac{1}{4(\pi N)^{\frac{3}{2}}} \phi(k_1) \phi(k_2) \tau(k_3) 2^{2\alpha} \frac{\Gamma(2\alpha + 9)}{\Gamma(2\alpha + 5)} \Gamma(\alpha + 4) $$

$$ \times \frac{\Gamma(2\alpha + 6)\Gamma(2\alpha + 6)}{\Gamma(2\alpha + 2)\Gamma(2\alpha + 2)} \Gamma(\alpha_1 + \frac{5}{2}) \Gamma(\alpha_2 + \frac{5}{2}) \Gamma(\alpha_3 + \frac{1}{2}), $$

$$ R_{i_1 i_2 i_3}^{sss} = \frac{1}{4(\pi N)^{\frac{3}{2}}} \phi(k_1) \sigma(k_2) \sigma(k_3) 2^{2\alpha} \Gamma(\alpha + 1) $$

$$ \times \frac{\Gamma(2\alpha + 3)\Gamma(2\alpha + 3)}{\Gamma(2\alpha + 2)\Gamma(2\alpha + 2)} \Gamma(\alpha_1 - \frac{1}{2}) \Gamma(\alpha_2 + \frac{3}{2}) \Gamma(\alpha_3 + \frac{3}{2}). $$
\[ R_{I_1I_2I_3}^{f^s} = \frac{1}{4(\pi N)^{5/2}} \phi(k_1)\sigma(k_2)\tau(k_3)2^{2\alpha} \frac{\Gamma(2\alpha + 4)\Gamma(2\alpha + 6)}{\Gamma(2\alpha + 3)\Gamma(2\alpha + 5)} \Gamma(\alpha + 3) \times \frac{\Gamma(2\alpha_1 + 1)\Gamma(2\alpha_1 + 3)\Gamma(2\alpha_2 + 3)\Gamma(2\alpha_2 + 7)\Gamma(2\alpha_2 + 9)\Gamma(2\alpha_3)}{\Gamma(2\alpha_1)\Gamma(2\alpha_1 + 2)\Gamma(2\alpha_2 + 2)\Gamma(2\alpha_2 + 4)\Gamma(2\alpha_2 + 6) \Gamma(2\alpha_3 + 1)} \times \Gamma(\alpha + \frac{3}{2})\Gamma(\alpha + \frac{7}{2}) \Gamma(\alpha - \frac{1}{2}), \]  
(3.11e)

\[ R_{I_1I_2I_3}^{f^t} = \frac{1}{4(\pi N)^{5/2}} \phi(k_1)\tau(k_2)\tau(k_3) \times 2^{2\alpha} \frac{\Gamma(2\alpha + 4)\Gamma(2\alpha + 6)\Gamma(2\alpha + 10)\Gamma(2\alpha + 12)}{\Gamma(2\alpha + 3)\Gamma(2\alpha + 5)\Gamma(2\alpha + 7)\Gamma(2\alpha + 9)} \Gamma(\alpha + 5) \times \frac{\Gamma(2\alpha_1 + 1)\Gamma(2\alpha_1 + 3)\Gamma(2\alpha_1 + 7)\Gamma(2\alpha_1 + 9)\Gamma(2\alpha_2 + 3)\Gamma(2\alpha_3 + 3)}{\Gamma(2\alpha_1)\Gamma(2\alpha_1 + 2)\Gamma(2\alpha_1 + 4)\Gamma(2\alpha_1 + 6) \Gamma(2\alpha_2 + 2) \Gamma(2\alpha_3 + 2)} \times \Gamma(\alpha + \frac{7}{2})\Gamma(\alpha + \frac{3}{2}) \Gamma(\alpha + \frac{3}{2}), \]  
(3.11f)

\[ R_{I_1I_2I_3}^{s^s} = \frac{1}{4(\pi N)^{5/2}} \sigma(k_1)\sigma(k_2)\sigma(k_3)2^{2\alpha} \Gamma(\alpha) \Gamma(\alpha + \frac{1}{2})\Gamma(\alpha + \frac{1}{2}) \Gamma(\alpha + \frac{1}{2}), \]  
(3.11g)

\[ R_{I_1I_2I_3}^{s^t} = \frac{1}{4(\pi N)^{5/2}} \sigma(k_1)\sigma(k_2)\tau(k_3)2^{2\alpha} \Gamma(\alpha + 2) \times \frac{\Gamma(2\alpha_1 + 6)\Gamma(2\alpha_2 + 6)}{\Gamma(2\alpha_1 + 2)\Gamma(2\alpha_2 + 2)} \Gamma(\alpha + \frac{5}{2})\Gamma(\alpha + \frac{5}{2}) \Gamma(\alpha - \frac{3}{2}), \]  
(3.11h)

\[ R_{I_1I_2I_3}^{t^s} = \frac{1}{4(\pi N)^{5/2}} \tau(k_1)\tau(k_2)\sigma(k_3)2^{2\alpha} \frac{\Gamma(2\alpha + 9)}{\Gamma(2\alpha + 5)} \Gamma(\alpha + 4) \times \frac{\Gamma(2\alpha_3 + 10)\Gamma(2\alpha_3 + 12)}{\Gamma(2\alpha_3 + 2)\Gamma(2\alpha_3 + 8)} \Gamma(\alpha + \frac{1}{2})\Gamma(\alpha + \frac{1}{2}) \Gamma(\alpha + \frac{9}{2}), \]  
(3.11i)

\[ R_{I_1I_2I_3}^{t^t} = \frac{1}{4(\pi N)^{5/2}} \tau(k_1)\tau(k_2)\tau(k_3)2^{2\alpha} \frac{\Gamma(2\alpha + 13)\Gamma(2\alpha + 15)}{\Gamma(2\alpha + 5)\Gamma(2\alpha + 11)} \Gamma(\alpha + 6) \times \frac{\Gamma(2\alpha_1 + 6)\Gamma(2\alpha_2 + 6)\Gamma(2\alpha_3 + 6)}{\Gamma(2\alpha_1 + 2)\Gamma(2\alpha_2 + 2)\Gamma(2\alpha_3 + 2)} \Gamma(\alpha + \frac{5}{2})\Gamma(\alpha + \frac{5}{2}) \Gamma(\alpha + \frac{5}{2}). \]  
(3.11j)

**AdS$_4 \times$ S$_7$**

In this case one has $\frac{1}{4\kappa^2} = \frac{N^2}{2^{11/2}10^3\pi^5}$ and $\epsilon = \frac{1}{2}$. One has

\[ \Delta_i^f = \frac{1}{2} k + 3, \]  
(3.12a)

\[ \Delta_i^s = \frac{1}{2} k, \]  
(3.12b)

\[ \Delta_i^t = \frac{1}{2} k + 6. \]  
(3.12c)

Set

\[ \phi(k) = \frac{1}{2} \left[ \frac{k!(k + 3)!}{(k + 4)!} \right]^{1/2}, \]  
(3.13a)
\[ \sigma(k) = [(k+1)!]^{\frac{1}{2}}, \quad \tau(k) = \frac{1}{4} \left[ \frac{k!(k+2)!(k+3)!(k+5)!}{(k+4)!(k+7)!(k+10)!} \right]^{\frac{1}{2}}. \]

Then,

\[
\bar{R}_{I_1I_2I_3}^{fff} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{4}} \phi(k_1)\phi(k_2)\phi(k_3) 2^{-\alpha} \frac{\Gamma(\alpha+5)}{\Gamma(\alpha+3) \Gamma(\frac{1}{2}\alpha+\frac{5}{2})} \frac{1}{\Gamma(\frac{1}{2}\alpha+2)} \\
\times \frac{\Gamma(\alpha_1+2)\Gamma(\alpha_2+2)\Gamma(\alpha_3+2)}{\Gamma(\alpha_1+1)\Gamma(\alpha_2+1)\Gamma(\alpha_3+1) \Gamma(\frac{1}{2}\alpha_1+1)\Gamma(\frac{1}{2}\alpha_2+1)\Gamma(\frac{1}{2}\alpha_3+1)},
\]

\[
\bar{R}_{I_1I_2I_3}^{ffs} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{4}} \phi(k_1)\phi(k_2)\sigma(k_3) 2^{-\alpha} \frac{1}{\Gamma(\frac{1}{2}\alpha+\frac{3}{2})} \\
\times \frac{\Gamma(\alpha_3+5)}{\Gamma(\alpha_3+1) \Gamma(\frac{1}{2}(\alpha_1+1))\Gamma(\frac{1}{2}(\alpha_2+1))\Gamma(\frac{1}{2}(\alpha_3+3))},
\]

\[
\bar{R}_{I_1I_2I_3}^{fft} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{4}} \phi(k_1)\phi(k_2)\tau(k_3) 2^{-\alpha} \frac{\Gamma(\alpha+8)}{\Gamma(\alpha+4) \Gamma(\frac{1}{2}\alpha+3)} \\
\times \frac{\Gamma(\alpha_1+5)\Gamma(\alpha_2+5)}{\Gamma(\alpha_1+1)\Gamma(\alpha_2+1) \Gamma(\frac{1}{2}(\alpha_1+3))\Gamma(\frac{1}{2}(\alpha_2+3))\Gamma(\frac{1}{2}(\alpha_3+1))},
\]

\[
\bar{R}_{I_1I_2I_3}^{fs} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{4}} \phi(k_1)\sigma(k_2)\sigma(k_3) 2^{-\alpha} \frac{1}{\Gamma(\frac{1}{2}\alpha+\frac{3}{2})} \\
\times \frac{\Gamma(\alpha_2+2)\Gamma(\alpha_3+2)}{\Gamma(\alpha_2+1)\Gamma(\alpha_3+1) \Gamma(\frac{1}{2}\alpha_1+1)\Gamma(\frac{1}{2}\alpha_2+1)\Gamma(\frac{1}{2}\alpha_3+1)},
\]

\[
\bar{R}_{I_1I_2I_3}^{fst} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{4}} \phi(k_1)\sigma(k_2)\tau(k_3) 2^{-\alpha} \frac{\Gamma(\alpha+5)}{\Gamma(\alpha+3) \Gamma(\frac{1}{2}\alpha+\frac{5}{2})} \\
\times \frac{\Gamma(\alpha_1+2)\Gamma(\alpha_2+8)\Gamma(\alpha_3)}{\Gamma(\alpha_1) \Gamma(\alpha_2+1) \Gamma(\alpha_3+1) \Gamma(\frac{1}{2}\alpha_1+1)\Gamma(\frac{1}{2}\alpha_2+2)\Gamma(\frac{1}{2}\alpha_3)},
\]

\[
\bar{R}_{I_1I_2I_3}^{fft} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{4}} \phi(k_1)\tau(k_2)\tau(k_3) 2^{-\alpha} \frac{\Gamma(\alpha+11)}{\Gamma(\alpha+3) \Gamma(\frac{1}{2}\alpha+\frac{7}{2})} \\
\times \frac{\Gamma(\alpha_1+8)\Gamma(\alpha_2+2)\Gamma(\alpha_3+2)}{\Gamma(\alpha_1) \Gamma(\alpha_2+1) \Gamma(\alpha_3+1) \Gamma(\frac{1}{2}\alpha_1+2)\Gamma(\frac{1}{2}\alpha_2+1)\Gamma(\frac{1}{2}\alpha_3+1)},
\]

\[
\bar{R}_{I_1I_2I_3}^{ss} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{4}} \sigma(k_1)\sigma(k_2)\sigma(k_3) 2^{-\alpha} \frac{1}{\Gamma(\frac{1}{2}\alpha+1)} \\
\times \frac{1}{\Gamma(\frac{1}{2}(\alpha_1+1))\Gamma(\frac{1}{2}(\alpha_2+1))\Gamma(\frac{1}{2}(\alpha_3+1))},
\]

\[
\bar{R}_{I_1I_2I_3}^{sst} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{4}} \sigma(k_1)\sigma(k_2)\tau(k_3) 2^{-\alpha} \frac{1}{\Gamma(\frac{1}{2}\alpha+2)} \\
\times \frac{1}{\Gamma(\alpha_1+1)\Gamma(\alpha_2+1) \Gamma(\frac{1}{2}(\alpha_1+3))\Gamma(\frac{1}{2}(\alpha_2+3))\Gamma(\frac{1}{2}(\alpha_3-1))},
\]
\[ R_{I_1 I_2 I_3}^{tts} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{2}} \tau(k_1) \tau(k_2) \sigma(k_3) 2^{-\alpha} \frac{\Gamma(\alpha + 8)}{\Gamma(\alpha + 4) \Gamma(\frac{1}{2} \alpha + 3)} \]
\[ \times \frac{\Gamma(\alpha + 3) \Gamma(\alpha_3 + 11)}{\Gamma(\alpha + 1) \Gamma(\alpha + 3)} \frac{1}{\Gamma(\alpha + 2) \Gamma(\frac{1}{2} \alpha + 1)} \frac{1}{\Gamma(\alpha_2 + 1)} \frac{1}{\Gamma(\alpha_3 + 5)}, \] (3.14i)

\[ R_{I_1 I_2 I_3}^{ttt} = \frac{\pi}{2} \left( \frac{2}{N} \right)^{\frac{3}{2}} \tau(k_1) \tau(k_2) \tau(k_3) 2^{-\alpha} \frac{\Gamma(\alpha + 8) \Gamma(\alpha + 14)}{\Gamma(\alpha + 1) \Gamma(\alpha + 6)} \frac{1}{\Gamma(\alpha_2 + 3)} \frac{1}{\Gamma(\alpha_3 + 5)} \] (3.14j)

**AdS\(_5 \times S_5\)**

In this case one has \( \frac{1}{4\kappa^2} = \frac{N^2}{8\pi} \) and \( \bar{e} = 1 \). One has

\[ \Delta_I^f = k + 4, \] (3.15a)
\[ \Delta_I^s = k, \] (3.15b)
\[ \Delta_I^t = k + 8. \] (3.15c)

Set

\[ \phi(k) = \left[ \frac{k!}{(k+3)!} \right]^{\frac{1}{2}}, \] (3.16a)
\[ \sigma(k) = k^{\frac{1}{2}}, \] (3.16b)
\[ \tau(k) = \left[ \frac{k!(k+1)!(k+2)!}{(k+5)!(k+6)!(k+7)!} \right]^{\frac{1}{2}}. \] (3.16c)

Then,

\[ R_{I_1 I_2 I_3}^{fff} = \frac{1}{N} \phi(k_1) \phi(k_2) \phi(k_3) \frac{\Gamma(\alpha + 4) \Gamma(\alpha_1 + 2) \Gamma(\alpha_2 + 2) \Gamma(\alpha_3 + 2)}{\Gamma(\alpha + 2) \Gamma(\alpha + 1) \Gamma(\alpha_2 + 1) \Gamma(\alpha_3 + 1)}, \] (3.17a)

\[ R_{I_1 I_2 I_3}^{fss} = \frac{1}{N} \phi(k_1) \phi(k_2) \sigma(k_3) \frac{\Gamma(\alpha + 3) \Gamma(\alpha_3 + 1) \Gamma(\alpha_3 + 2)}{\Gamma(\alpha + 1) \Gamma(\alpha + 2) \Gamma(\alpha_2 + 2)}, \] (3.17b)

\[ R_{I_1 I_2 I_3}^{fft} = \frac{1}{N} \phi(k_1) \phi(k_2) \tau(k_3) \frac{\Gamma(\alpha + 5) \Gamma(\alpha + 6)}{\Gamma(\alpha + 3) \Gamma(\alpha + 4)} \] \[ \times \frac{\Gamma(\alpha_1 + 3) \Gamma(\alpha_1 + 4) \Gamma(\alpha_2 + 3) \Gamma(\alpha_2 + 4)}{\Gamma(\alpha_1 + 1) \Gamma(\alpha_1 + 2) \Gamma(\alpha_2 + 1) \Gamma(\alpha_2 + 2)}, \] (3.17c)

\[ R_{I_1 I_2 I_3}^{sts} = \frac{1}{N} \phi(k_1) \sigma(k_2) \sigma(k_3) \frac{\Gamma(\alpha + 2) \Gamma(\alpha_3 + 2)}{\Gamma(\alpha_2 + 1) \Gamma(\alpha_3 + 1)}, \] (3.17d)

\[ R_{I_1 I_2 I_3}^{fst} = \frac{1}{N} \phi(k_1) \sigma(k_2) \tau(k_3) \frac{\Gamma(\alpha + 4)}{\Gamma(\alpha + 2)} \]
\[ \frac{\Gamma(\alpha_1 + 2) \Gamma(\alpha_2 + 5) \Gamma(\alpha_2 + 6) \Gamma(\alpha_3)}{\Gamma(\alpha_1) \Gamma(\alpha_2 + 1) \Gamma(\alpha_2 + 3) \Gamma(\alpha_3 + 1)}, \quad (3.17e) \]

\[ R_{I_1 I_2 I_3}^{f t t} = \frac{1}{N} \phi(k_1) \tau(k_2) \tau(k_3) \frac{\Gamma(\alpha + 7) \Gamma(\alpha + 8)}{\Gamma(\alpha + 2) \Gamma(\alpha + 5)} \times \frac{\Gamma(\alpha_1 + 5) \Gamma(\alpha_1 + 6) \Gamma(\alpha_2 + 2) \Gamma(\alpha_3 + 2)}{\Gamma(\alpha_1 + 1) \Gamma(\alpha_2 + 3) \Gamma(\alpha_2 + 1) \Gamma(\alpha_3 + 1)}, \quad (3.17f) \]

\[ R_{I_1 I_2 I_3}^{s s s} = \frac{1}{N} \sigma(k_1) \sigma(k_2) \sigma(k_3), \quad (3.17g) \]

\[ R_{I_1 I_2 I_3}^{s s t} = \frac{1}{N} \sigma(k_1) \sigma(k_2) \tau(k_3) \frac{\Gamma(\alpha + 3) \Gamma(\alpha_1 + 4) \Gamma(\alpha_2 + 3) \Gamma(\alpha_2 + 4)}{\Gamma(\alpha_1 + 1) \Gamma(\alpha_1 + 2) \Gamma(\alpha_2 + 1) \Gamma(\alpha_2 + 2)}, \quad (3.17h) \]

\[ R_{I_1 I_2 I_3}^{t t s} = \frac{1}{N} \tau(k_1) \tau(k_2) \sigma(k_3) \frac{\Gamma(\alpha + 5) \Gamma(\alpha + 6) \Gamma(\alpha_3 + 7) \Gamma(\alpha_3 + 8)}{\Gamma(\alpha + 3) \Gamma(\alpha + 4) \Gamma(\alpha_3 + 1) \Gamma(\alpha_3 + 2)}, \quad (3.17i) \]

\[ R_{I_1 I_2 I_3}^{t t t} = \frac{1}{N} \tau(k_1) \tau(k_2) \tau(k_3) \frac{\Gamma(\alpha + 9) \Gamma(\alpha + 10)}{\Gamma(\alpha + 3) \Gamma(\alpha + 4)} \times \frac{\Gamma(\alpha_1 + 3) \Gamma(\alpha_1 + 4) \Gamma(\alpha_2 + 3) \Gamma(\alpha_2 + 4) \Gamma(\alpha_3 + 3) \Gamma(\alpha_3 + 4)}{\Gamma(\alpha_1 + 1) \Gamma(\alpha_2 + 1) \Gamma(\alpha_2 + 2) \Gamma(\alpha_3 + 1) \Gamma(\alpha_3 + 2)}. \quad (3.17j) \]

It is useful to remember that the value of the integer \( k \) of the operators \( O_s^I, O_f^I, O_t^I \) belonging to the same multiplet are related as follows

\[ k^s = k, \quad k^f = k - 2, \quad k^t = k - 4. \quad (3.18) \]

Some of these results have been obtained by other groups as well. Namely, in the SCFT\(_4\) case, the 3-point function of the chiral primary operators eq. \((3.17g)\) was produced in the seminal paper [13], while eq. \((3.17h)\) was contained in [17]. As for SCFT\(_6\), eq. \((3.11g)\) was calculated in [15], though that result differs for a factor from ours [23]. We have computed in previous works the s–t correlations functions [23,24], extended here above to the full universal sector.

4. Conclusions

We have computed in a systematic way the large \( N \) limit of the 3-point functions of the scalars belonging to the universal sector which is common to all of the maximal supersymmetric CFT in \( d = 3, 4, 6 \). The infrared dynamics of the M2, D3 and M5 branes belongs to the universality classes identified by these SCFT\(_3,4,6\), and in fact we used the AdS/CFT correspondence to compute some scalar correlation functions in the latter. That constitutes the main result of this paper.

At large \( N \), all the operators group into short (also called chiral) supersymmetric multiplets [31–35]. In particular, the operators \( O^s \) are the chiral primaries which generate
all of the other by application of the superconformal algebra \([36,37]\). In \(d = 4\) it was shown in \([38]\) by using a superspace approach that the 3-point function of all chiral operators are fixed by a unique superspace conformal invariant up to a single coefficient, which can be easily read off from \(\langle O^a O^b O^c \rangle\). Thus, it should be possible to obtain the correlation functions of the descendants, including the ones listed in section 3, by such superspace techniques, though this may be laborious. A similar strategy has not been worked out for the SCFT\(3,6\), to our knowledge, and it is not known how many independent numbers describe the correlation functions of the chiral multiplets. Investigation of the stress tensor 3-point functions (belonging to the family identified by the chiral primary with \(k = 2\)) show only a single overall coefficient for all of the SCFT\(3,6\) \([39]\), and this may suggest that also in these new cases supersymmetry fixes the correlations function of chiral multiplets up to a constant. It would indeed be interesting to develop a superspace approach and reproduce the descendant correlation functions from the chiral ones. More importantly, it would be nice to investigate their \(\frac{1}{N}\) corrections. On the other hand, the general model we used to obtain the scalar 3-point function can still be employed to compute the 4-point functions of the chiral primaries in a systematic way for the SCFT\(3,4,6\). In the light of some results for the super Yang Mills case \([20]\), that might be a formidable task but still within the reach of future research.

**A1. Spherical Harmonics**

We describe the \(n\)-dimensional sphere \(S_n\) of radius \(\rho\) as \(S_n = \{ x \in \mathbb{R}^{n+1} | x^2 = \rho^2 \}\).

Since \(S_n \subset \mathbb{R}^{n+1}\), we can represent tensor fields on \(S_n\) by means of tensor fields on \(\mathbb{R}^{n+1}\) of the same type satisfying certain conditions. Since further \(S_n\) is naturally equipped with the metric induced by the Euclidean metric of \(\mathbb{R}^{n+1}\), we need not distinguish covariant and contravariant tensor indices. Specifically, a rank \(s\) tensor field \(T_{\alpha_1...\alpha_s}\) on \(S_n\) may be viewed as a rank \(s\) tensor field \(T_{i_1...i_s}\) defined on a neighborhood of \(S_n \subset \mathbb{R}^{n+1}\) with no components normal to \(S_n\):

\[
x_i T_{i_1...i_a...i_{a+1}...i_s}(x) = 0, \quad 1 \leq a \leq s. \quad (A1.1)
\]

In particular, the induced metric \(g_{\alpha\beta}\) of \(S_n\) is represented by

\[
g_{ij}(x) = \delta_{ij} - \frac{x_i x_j}{r^2}, \quad (A1.2)
\]

where \(r = (x_i x_i)^{\frac{1}{2}}\). Therefore, the contraction of two rank \(s\) tensor fields \(T_{\alpha_1...\alpha_s}, U_{\alpha_1...\alpha_s}\) is given by

\[
T^{\alpha_1...\alpha_s} U_{\alpha_1...\alpha_s} = T_{i_1...i_s} U_{i_1...i_s}. \quad (A1.3)
\]
For a rank $s$ tensor field $T_{\alpha_1...\alpha_s}$, the covariant derivative $\nabla_{\alpha} T_{\alpha_1...\alpha_s}$ is represented by

$$\nabla_i T_{i_1...i_s}(x) = \left( \partial_i - \frac{x_i}{r} \partial_r \right) T_{i_1...i_s}(x) + \sum_{a=1}^{s} \frac{x_{ia}}{r^2} T_{i_1...i_{a-1}i_{a+1}...i_s}(x), \tag{A1.4}$$

where $\partial_r = \partial/\partial r$.

For any function $F$ on $S_n$, the integral of $F$ on $S_n$ is given by

$$\int_{S_n} d^n \text{vol} F = \int_{S_n} r^n d\Omega_n(x) F(x) \bigg|_{r=\rho}, \tag{A1.5}$$

where $d\Omega_n(x)$ is the standard $n$ dimensional volume on $S_n$ defined as usual by $d^{n+1}x = r^ndr d\Omega_n(x)$.

Using the above integration formula, one can provide the space of rank $s$ tensor fields with a Hilbert space structure in obvious fashion.

Consider the rank $s$ tensor fields

$$Y^{(s)}_{I_1...i_s}(x) = Y^{(s)}_{I_1...i_s;j_1...j_k} r^{-k} x_{j_1} ... x_{j_k}, \tag{A1.6}$$

where the $Y^{(s)}_{I_1...i_s;j_1...j_k}$ are constants satisfying the following conditions:

i) $Y^{(s)}_{I_1...i_s;j_1...j_k}$ is symmetric and traceless in $i_1, ..., i_s$;

ii) $Y^{(s)}_{I_1...i_s;j_1...j_k}$ is symmetric and traceless in $j_1, ..., j_k$;

iii) the following relation holds

$$Y^{(s)}_{I_1...i_s-1\{i_s; j_1...j_k\}} = 0, \tag{A1.7}$$

where $\{\ldots\}$ denotes total symmetrization.

The index $I$ labels the different choices of the constants $Y^{(s)}_{I_1...i_s;j_1...j_k}$. Note that $Y^{(s)}_{I_1...i_s}$ is characterized by the non negative integer $k$, which may be thought of as a function of the label $I$. It can be shown that, if $Y^{(s)}_{I_1...i_s} \neq 0$, then necessarily $k \geq s$.

Then, the $Y^{(s)}_{I_1...i_s}$ are symmetric traceless rank $s$ tensor fields on $S_n$. Further, they are divergenceless (transversal):

$$\nabla_i Y^{(s)}_{I_1...i_s} = 0, \tag{A1.8}$$

Finally, the $Y^{(s)}_{I_1...i_s}$ are eigenfields of the Laplacian:

$$-\nabla_i \nabla_i Y^{(s)}_{I_1...i_s} = \frac{1}{r^2} [(k(k + n - 1) - s] Y^{(s)}_{I_1...i_s}. \tag{A1.9}$$

If, for fixed $s$, we choose a maximal set of constants $Y^{(s)}_{I_1...i_s;j_1...j_k}$ such that

$$Y^{(s)}_{I_1...i_s;j_1...j_k} Y^{(s)}_{J_1...i_s;j_1...j_k} = \delta_{IJ} \tag{A1.10}$$
for all \( k \), then, the tensor fields \( \{ Y^{(s)}_{I_1 \ldots I_s} | I \} \) provide an orthogonal basis of the space of divergenceless symmetric traceless rank \( s \) tensor fields on \( S_n \).

In concrete applications, one has to compute the integrals of scalars formed by contraction of several tensor spherical harmonics \( Y^{(s)} \) and their covariant derivatives. This can be done by a systematic use of the formula

\[
\int_{S^n} r^n \Omega_n(x) r^{-2m} x^{i_1} \ldots x^{i_{2m}} \bigg|_{r=\bar{r}} = \rho^n \omega_n \frac{(n-1)!!}{(2m+n-1)!!} \times (\text{all possible Wick contractions}), \quad (A1.11)
\]

where “all possible Wick contractions” are given by the sum of \((2m-1)!!\) terms obtained by using \( \langle r^{-2} x^i x^j \rangle = \delta^{ij} \) as elementary Wick contraction and \( \omega_n \) is the volume of the unit sphere

\[
\omega_n = \frac{2\pi^{n+1}}{\Gamma\left(\frac{n+1}{2}\right)}.
\]  

The results are always expressible in terms of suitable contractions of the coefficients \( \mathcal{Y}^{(s)}_{I_1 \ldots I_s} \), generically denoted as \( \langle \prod_{I} \mathcal{Y}^{(s)}_{I} \rangle \) and certain numerical functions of the \( k_I \).

For two and three tensor spherical harmonics, the only such functions are

\[
z_I = \omega_n \frac{(n-1)!!k!}{(2k+n-1)!!},
\]

\[
ad_{I_1 I_2 I_3} = \omega_n \frac{(n-1)!!k_1!k_2!k_3!}{(2\alpha+n-1)!!\alpha_1!\alpha_2!\alpha_3!}.
\]

where

\[
\alpha_1 = \frac{1}{2}(k_2 + k_3 - k_1), \quad \alpha_2 = \frac{1}{2}(k_3 + k_1 - k_2), \quad \alpha_3 = \frac{1}{2}(k_1 + k_2 - k_3),
\]

\[
\alpha = \frac{1}{2}(k_1 + k_2 + k_3).
\]

In this paper, \( \rho = \bar{e}^{-1} \). Further, we consider only \( s = 0, 2 \). We set \( \mathcal{C}_{I_1 \ldots I_k} = \mathcal{Y}^{(0)}_{I_1 \ldots I_k} \) and \( \mathcal{T}_{I_1 I_2 : I_3 ; I_4 ; I_5 ; \ldots ; I_k} = \mathcal{Y}^{(2)}_{I_1 I_2 ; I_3 ; \ldots ; I_k} \).

The main contractions are the following. \( \langle \mathcal{C}_{I_1} \mathcal{C}_{I_2} \mathcal{C}_{I_3} \rangle \) denotes the unique \( SO(n+1) \) scalar contraction of three tensors \( \mathcal{C}_{I_1 \ldots I_k} \) and in a similar fashion we define

\[
\langle \mathcal{T}_{I_1} \mathcal{T}_{I_2} \mathcal{T}_{I_3} \rangle = \langle \mathcal{T}_{I_1 ab} \mathcal{T}_{I_2 ac} \mathcal{T}_{I_3 bc} \rangle \quad (A1.16a)
\]

\[
\langle \mathcal{T}_{I_1} \mathcal{T}_{I_2} \mathcal{T}_{I_3} \rangle = \langle \mathcal{T}_{I_1 ab} \mathcal{T}_{I_2 ac} \mathcal{T}_{I_3 bc} \rangle \quad (A1.16b)
\]

\[
\langle \mathcal{T}_{I_1} \mathcal{T}_{I_2} \mathcal{T}_{I_3} \rangle = 4 \langle \mathcal{T}_{I_1 ab} \mathcal{T}_{I_2 ac} \mathcal{T}_{I_3 bc} \rangle + \sum_{c.p.123} \alpha_1 \left(2 \langle \mathcal{T}_{I_1 ab} \mathcal{T}_{I_2 ac} \mathcal{T}_{I_3 bc} \rangle + \langle \mathcal{T}_{I_1 ab} \mathcal{T}_{I_2 cd} \mathcal{T}_{I_3 cd} \rangle \right) \quad (A1.16c)
\]
where on the right hand side one takes the unique contraction of the hidden indices, and where the notation c.p.123 stands for cyclic permutations of 123.

**A2. Auxiliary functions**

Here is the complete list of the auxiliary functions $F$ appearing in (2.4a) – (2.4j).

\[
F^{fss} = (D - 2)\alpha_2\alpha_3 \quad \text{(A2.1a)}
\]

\[
F^{fft} = (D - 2)\alpha_2\alpha_3 \quad \text{(A2.1b)}
\]

\[
F^{fst} = (D - 2)\alpha_1(\alpha + 1 + p) \quad \text{(A2.1c)}
\]

\[
F^{sss} = (1 + p)(D - 3 - p)(\alpha_1^2\alpha_2 + \alpha_2^2\alpha_1 + \alpha_2^2\alpha_3 + \alpha_3^2\alpha_2 + \alpha_3^2\alpha_1 + \alpha_1^2\alpha_3)
\]

\[
+ (3D - 8 + (2D - 8)p - 2p^2)\alpha_1\alpha_2\alpha_3
\]

\[
+ (1 + p)(-\frac{1}{2}D + 2 + p)(\alpha_1\alpha_2 + \alpha_2\alpha_3 + \alpha_3\alpha_1) \quad \text{(A2.1d)}
\]

\[
F^{sst} = (1 + p)(D - 3 - p)(\alpha_1^2\alpha_3 + \alpha_3^2\alpha_1 + \alpha_2^2\alpha_3 + \alpha_3^2\alpha_2)
\]

\[
+ (-1 + (D - 4)p - p^2)(\alpha_1^2\alpha_2 + \alpha_2^2\alpha_1)
\]

\[
+ (D - 4 + (2D - 8)p - 2p^2)\alpha_1\alpha_2\alpha_3
\]

\[
+ (1 + p)p(D - 3 - p)(\alpha_1\alpha_3 + \alpha_2\alpha_3)
\]

\[
+ (1 + p)(-D + 2 + (D - 3)p - p^2)\alpha_1\alpha_2
\]

\[
+ (1 + p)(D - 3 - p)(-\alpha_1^2 - \alpha_2^2 + (1 + p)\alpha_3^2)
\]

\[
+ (1 + p)^2(-D + 3 + p)(\alpha_1 + \alpha_2 + \alpha_3) \quad \text{(A2.1e)}
\]

\[
F^{tts} = (1 + p)(D - 3 - p)(\alpha_1^2\alpha_3 + \alpha_3^2\alpha_1 + \alpha_2^2\alpha_3 + \alpha_3^2\alpha_2)
\]

\[
+ (-1 + (D - 4)p - p^2)(\alpha_1^2\alpha_2 + \alpha_2^2\alpha_1)
\]

\[
+ (D - 4 + (2D - 8)p - 2p^2)\alpha_1\alpha_2\alpha_3
\]

\[
+ (1 + p)(\frac{5}{2}D - 8 + (2D - 9)p - 2p^2)(\alpha_1\alpha_3 + \alpha_2\alpha_3)
\]

\[
+ (1 + p)(\frac{3}{2}D - 6 + (2D - 9)p - 2p^2)\alpha_1\alpha_2
\]

\[
+ (1 + p)(\frac{3}{2}D - 5 + (D - 5)p - p^2)(\alpha_1^2 + \alpha_2^2)
\]

\[
+ (1 + p)^2(\frac{3}{2}D - 5 + (D - 5)p - p^2)(\alpha_1 + \alpha_2) \quad \text{(A2.1f)}
\]
\[ F^{ttt} = (1 + p)(D - 3 - p)(\alpha_1^2 \alpha_2 + \alpha_2^2 \alpha_1 + \alpha_2^2 \alpha_3 + \alpha_3^2 \alpha_2 + \alpha_3^2 \alpha_1 + \alpha_1^2 \alpha_3) \]
\[ + (3D - 8 + (2D - 8)p - 2p^2)\alpha_1 \alpha_2 \alpha_3 \]
\[ + (1 + p)(4D - 13 + (3D - 14)p - 3p^2)(\alpha_1 \alpha_2 + \alpha_2 \alpha_3 + \alpha_3 \alpha_1) \]
\[ + (1 + p)^2(D - \frac{7}{2} - p)(\alpha_1^2 + \alpha_2^2 + \alpha_3^2) \]
\[ + (1 + p)^2(3D - 11 + (2D - \frac{21}{2})p - 2p^2)(\alpha_1 + \alpha_2 + \alpha_3) \]
\[ + (2 + p)(1 + p)^3(D - 4 - p) \]  
\text{(A2.1g)}
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