(Super)Current Correlators in Strongly Coupled Gauge Theories

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Based on:

RA, Bertolini, Di Pietro, Porri and Redigolo

- arXiv:1205.4709 [hep-th]
- arXiv:1208.3615 [hep-th]
- to appear

2-point correlators of gauge invariant operators contain lots of information.

- Euclidean momentum: UV asymptotics, IR phases
- Minkowskian momentum: spectrum of theory (resonances)

Our aim:

We want to compute 2-point functions of operators related by SUSY.

- When SUSY is unbroken, the different 2-point functions must be related. (E.g. the propagators.)
- When SUSY is broken the 2-point functions will differ at low momenta/large distances.

Which gauge invariant operators are most interesting?

- operators in the supercurrent multiplet
- operators in a conserved current supermultiplet

We will be interested in strongly coupled, SUSY breaking gauge theories—hidden sectors.

Their correlators are useful, respectively, to investigate the main features of the hidden sector, and as main ingredients in implementing General Gauge Mediation.

Supercurrent supermultiplet (Ferrara-Zumino)

$$\mathcal{J}_\mu^* = \mathcal{J}_\mu \,, \quad -2\,\bar{D}^{\dot\alpha}\sigma^\mu_{\alpha\dot\alpha}\,\mathcal{J}_\mu = D_\alpha X \,, \quad \bar{D}_{\dot\alpha} X = 0$$

$$\mathcal{J}_\mu = j_\mu^R + \theta S_\mu + \bar\theta \bar S_\mu + \theta\sigma^\nu\bar\theta 2T_{\mu\nu} + \dots$$

and

$$X = x + \frac{2}{3}\theta S + \theta^2\left(\frac{2}{3}T + i\,\partial^\mu j_\mu^R\right) + \dots$$

Stress-energy tensor $T_{\mu\nu}$ and supercurrent S_μ are conserved (in a SUSY theory).

The superconformal R-current j_μ^R is conserved if and only if conformal symmetry is preserved.

Correlators of operators in the FZ multiplet

$$\langle x(k)\, x^*(-k)\rangle = \tfrac{2}{3}\, k^2\, F_0(k^2)$$
$$\langle j^R_\mu(k)\, j^R_\nu(-k)\rangle = -P_{\mu\nu}\, C_{1R}(k^2) - \tfrac{1}{3}\, k^2 \eta_{\mu\nu}\, F_1(k^2)$$
$$\langle T_{\mu\nu}(k)\, T_{\rho\sigma}(-k)\rangle = -\tfrac{1}{8} X_{\mu\nu\rho\sigma}\, C_2(k^2) - \tfrac{1}{8}\left(P_{\mu\nu} P_{\rho\sigma} - P_{\rho(\mu} P_{\nu)\sigma} \right) F_2(k^2)$$
$$\langle S_{\mu\alpha}(k)\, \bar{S}_{\nu\dot\beta}(-k)\rangle = -(Y_{\mu\nu})_{\alpha\dot\beta}\, C_{3/2}(k^2) - \tfrac{i}{2}\, k^2\, \varepsilon_{\mu\nu\rho\lambda}\, k^\rho \sigma^\lambda_{\alpha\dot\beta}\, F_{3/2}(k^2) + \text{S.T.}$$

- $F_s = 0$ when conformal symmetry is not explicitly broken.
- Poles in the above correlators if (super)symmetries are spontaneously broken.
- Schwinger terms in the supercurrent correlators need to be included when SUSY is spontaneously broken.
- There are many other complex form factors, not shown here.

SUSY imposes $C_{1R} = C_2 = C_{3/2}$ and $F_0 = F_1 = F_2 = F_{3/2}$.

Conserved current supermultiplet: $\mathcal{J}^* = \mathcal{J}\,, \quad D^2\mathcal{J} = 0$

$$\mathcal{J} = J + \theta^\alpha j_\alpha + \bar\theta_{\dot\alpha}\bar j^{\dot\alpha} + \theta\sigma^\mu\bar\theta j_\mu + \ldots$$

Correlators are

$$\begin{aligned}
\langle J(k)J(-k)\rangle &= C_0(k^2)\,,\\
\langle j_\alpha(k)\bar j_{\dot\alpha}(-k)\rangle &= \sigma^\mu_{\alpha\dot\alpha}k_\mu C_{1/2}(k^2)\,,\\
\langle j_\mu(k)j_\nu(-k)\rangle &= (k_\mu k_\nu - \eta_{\mu\nu}k^2)C_1(k^2)\,,\\
\langle j_\alpha(k)j_\beta(-k)\rangle &= \epsilon_{\alpha\beta}B_{1/2}(k^2)\,.
\end{aligned}$$

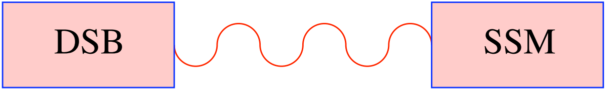
When SUSY preserved:

$$C_0(k^2) = C_{1/2}(k^2) = C_1(k^2), \qquad B_{1/2}(k^2) = 0$$

This is familiar with the formalism of General Gauge Mediation.

Gauge Mediation of SUSY breaking

SUSY breaking must be communicated through higher dimension operators. This leads to the mediation paradigm:



- hidden sector with (dynamical) SUSY breaking
- visible SSM sector
- mediating fields in between: SM gauge fields (vector supermultiplet)

Formalism of General Gauge Mediation: [Meade, Seiberg, Shih 08]

The SSM soft spectrum is then determined as follows:

- Sfermion masses

$$m_{\tilde{f}}^2 = -g^4 \int \frac{d^4k}{(2\pi)^4} \frac{1}{k^2} \left(C_0(k^2) - 4C_{1/2}(k^2) + 3C_1(k^2) \right)$$

- (Majorana) Gaugino masses

$$m_\lambda = g^2 B_{1/2}(0)$$

$C_s(k^2)$ and $B_{1/2}(k^2)$ are the only data we need to import from the hidden sector in order to determine the SSM soft terms.

How do we compute the correlators $C_s(k^2)$, $F_s(k^2)$ and $B_{1/2}(k^2)$ in a strongly coupled hidden sector?

Holography!

Strongly coupled 4d field theories from 5d near-AdS gravitational theories.

Vacua of the gauge theories correspond to specific solutions (backgrounds) in the gravity theory.

Gauge invariant operators correspond to classical fields in the bulk.

Quantum correlators are computed from fluctuations over the background and a (classical) renormalization procedure.

An early attempt is Holographic Gauge Mediation. [Benini et al, McGuirk et al 09]

More specific to our set up:

- 4d $\mathcal{N} = 1$ SUSY corresponds 5d $\mathcal{N} = 2$ gauged SUGRA.
- Hidden sector provided by Asymptotically AdS background.

The FZ multiplet in 4d corresponds to the gravity supermultiplet in 5d, which contains also the graviphoton as the dual of the R-current.
It is always present!

A current supermultiplet in 4d is dual to a vector multiplet of 5d gauged SUGRA.

The correspondence reads

FZ supermultiplet

$$
\begin{array}{lllll}
T_{\mu\nu}(x) & \Delta = 4 & \Rightarrow & G_{MN}(z,x) & m_G = 0 \\
S_{\mu\alpha}(x) & \Delta = 7/2 & \Rightarrow & \psi_M(z,x) & |m_\psi| = 3/2 \\
j^R_\mu(x) & \Delta = 3 & \Rightarrow & \tilde{A}_M(z,x) & m_{\tilde{A}} = 0
\end{array}
$$

Current supermultiplet

$$
\begin{array}{lllll}
j_\mu(x) & \Delta = 3 & \Rightarrow & A_M(z,x) & m_A = 0 \\
j_\alpha(x) & \Delta = 5/2 & \Rightarrow & \lambda(z,x) & |m_\lambda| = 1/2 \\
J(x) & \Delta = 2 & \Rightarrow & D(z,x) & m_D^2 = -4
\end{array}
$$

In order to compute 2-point functions of the operators on the left (4d), we need to compute fluctuations at quadratic order of the fields on the right (5d).

What about the background?

We choose it to be Asymptotically AdS

$$ds_5^2 = \frac{1}{z^2}(F(z)d\vec{x}^2 + dz^2) \underset{z\to 0}{\simeq} \frac{1}{z^2}(d\vec{x}^2 + dz^2)$$

with possibly

- a dilaton profile $\phi(z)$ to break conformality and SUSY
- a profile for another scalar $\eta(z)$ that breaks R-symmetry.

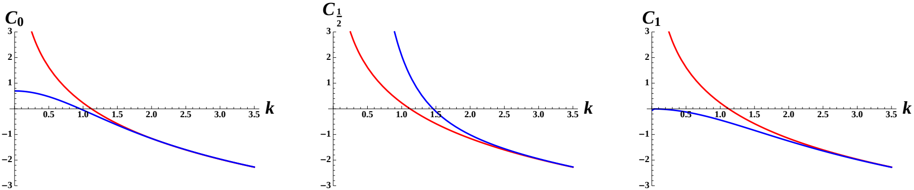
It turns out that the 5d universal hypermultiplet contains both needed scalars.

Both top-down (10d SUGRA) and bottom-up (hard-wall) approaches.

Since background is AAdS, the $C_s(k^2)$ functions should asymptote to those in AdS for large k:

$$C_0^{AdS}(k^2) = C_{1/2}^{AdS}(k^2) = C_1^{AdS}(k^2) = \frac{N^2}{8\pi^2}\log\left(\frac{\Lambda^2}{k^2}\right)$$

Typical results for a background with no R-symmetry breaking ($\eta = 0$):



Red AdS, Blue dilaton domain-wall.

In particular, we find $C_{1/2}$ which has a pole $1/k^2$ for $k \to 0$.

This is a signature of the presence of massless fermions in the IR.

The most plausible possibility is that these are ’t Hooft fermions due to the global anomaly of the $SU(4)$ R-symmetry.

Notable consequence for gauge mediation:

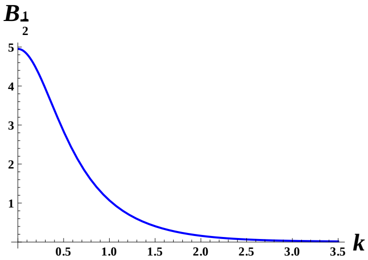
Despite $B_{1/2} = 0$, the SSM gauginos acquire dynamically a mass of Dirac type (as in super Higgs mechanism).

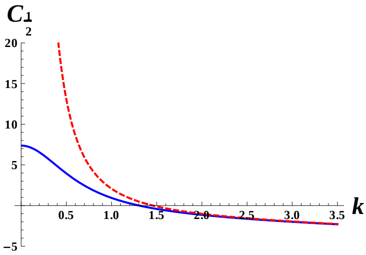
In order to have a model of strongly coupled hidden sector leading to $B_{1/2} \neq 0$, and gauge-mediated Majorana gaugino masses

$\Rightarrow$ we need to find a background with a non-trivial η profile.

In bottom-up approach: allow for more general boundary conditions at the wall.

In a background with broken R-symmetry we obtain the form factors:





The results are:

- $B_{1/2}(k^2)$ which controls the gaugino Majorana mass is non-zero.
- The IR massless pole in $C_{1/2}(k^2)$ disappears.
- On the field theory side we do not expect massless 't Hooft fermions since R-symmetry is broken.

FZ multiplet:

Testing the features of the background.

E.g. conformality (and R-symmetry) spontaneously broken, SUSY unbroken.

Hard wall model simplest setting: analytical correlators.

$$C_{1R} = C_2 = C_{3/2} = \frac{N^2}{24\pi^2}\left(\log\frac{\Lambda^2}{k^2} + 2\frac{K_1(k/\mu)}{I_1(k/\mu)}\right) \underset{k^2\to 0}{\simeq} \frac{N^2}{6\pi^2}\frac{\mu^2}{k^2}$$

Dilaton, dilatino and R-axion massless poles!

Many other situations left to investigate... [Stay tuned!]

Outlook

In the short term: [Work in progress]

- Backreaction of η scalar to study m_λ/m_s.
- Correlators of the operators in the supercurrent multiplet in more general situations (broken SUSY) and backreacted backgrounds.
- Stability of backgrounds with singularity in the bulk: no tachyons in the spectrum for all fluctuations

In the long run:

- Go to non AAdS (e.g. cascading KS like) backgrounds
- Include D7-branes
- Other uses than GGM: Technicolor, RS-like model building, BSM physics, ...