Janus and J-folds

Friðrik Freyr Gautason

Recent Developments in Strings and Gravity
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based on [1907.11132] with Nikolay Bobev, Krzysztof Pilch, Minwoo Suh, and Jesse van Muiden

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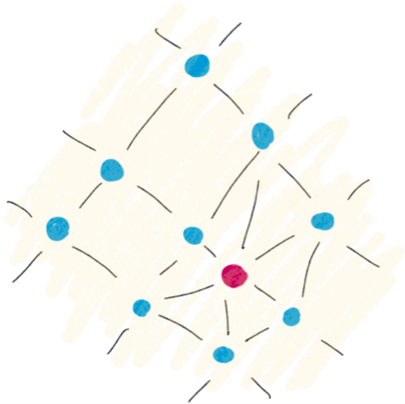

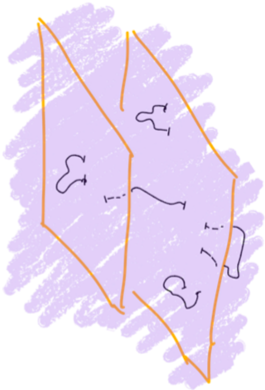

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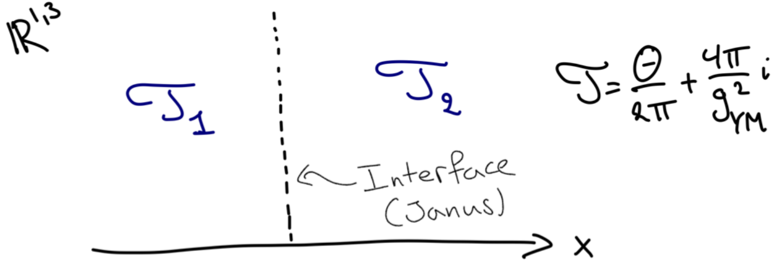
In $\mathcal{N} = 4$ SYM they arise from studying the theory with a position dependent coupling.



JANUS IN $\mathcal{N} = 4$

The Janus configurations can preserve a lot of supersymmetry

D'Hoker, Estes, Gutperle (2006)

$\mathcal{N}$	supergroup	R-symmetry	Commutant
4	$\mathrm{OSp}(4\|4, \mathbf{R})$	$\mathrm{SU}(2) \times \mathrm{SU}(2)$	
2	$\mathrm{OSp}(2\|4, \mathbf{R})$	$\mathrm{U}(1)$	$\mathrm{SU}(2)$
1	$\mathrm{OSp}(1\|4, \mathbf{R})$		$\mathrm{SU}(3)$
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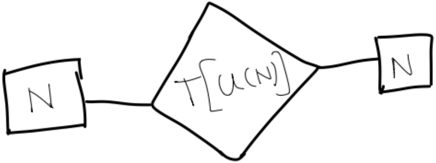
The $\mathrm{U}(N)$ $\mathcal{N} = 4$ interface has been studied extensively on the field theory side. The conformally invariant interfaces are closely related to strongly coupled 3D $\mathcal{N} = 4$ Chern Simons like theories called $T[\mathrm{U}(N)]$.

Gaiotto, Witten (2009-10)

Janus in $\mathcal{N} = 4$

The 3D $\mathcal{N} = 4$ SCFTs of Gaiotto and Witten serve as new strongly coupled building blocks.



The two boxes denote two copies of $\mathrm{U}(N)$ flavor symmetry.

New 3D SCFTs: J-folds

We can build new strongly coupled SCFTs in three dimensions using this building block. For example gauging the diagonal $\mathrm{U}(N)$ flavor symmetries and adding a Chern-Simons level n

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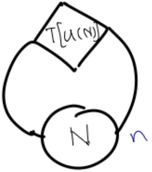

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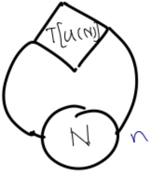

These theories are called J-folds. Sidenote: Naively the CS level breaks supersymmetry from $\mathcal{N} = 4$ to $\mathcal{N} = 3$ but there is an IR enhancement to $\mathcal{N} = 4$. Recent success by Assel and Tomasiello in matching a supergravity analysis with a localization for the $\mathcal{N} = 4$ J-fold theories.

Main claim of this talk: Very similar story also holds starting from any $\mathcal{N} = 1$ SCFT in four dimensions *with* a marginal coupling.

Holography

4D $\mathcal{N} = 1$ SCFTs in type IIB

Start with type IIB on

$$\mathbf{R}^{1,3} \times \mathrm{CY}_3$$

where $\mathrm{CY}_3 = \mathcal{C}(\mathrm{SE}_5)$.

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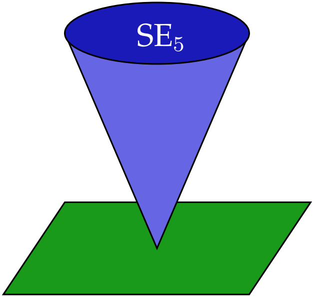

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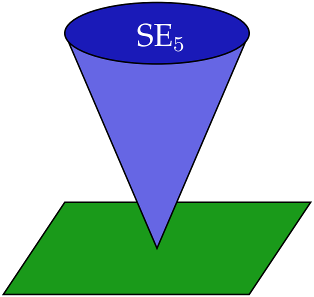

The holographic dual to D3-branes probing $\mathcal{C}(\mathrm{SE}_5)$ is

$$\mathrm{AdS}_5 \times \mathrm{SE}_5 \ .$$

4D $\mathcal{N} = 1$ SCFTs in type IIB

All these SCFTs have a marginal coupling dual to the axion-dilaton in type IIB.

We use a consistent truncation of type IIB on SE_5 to a $\mathcal{N} = 2$ supergravity in five dimensions coupled to a single hypermultiplet.

Cassani, Dall'Agata, Faedo (2010)
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This approach considerably simplifies our search for the dual to a Janus configuration and J-folds starting from the $\mathcal{N} = 1$ SCFTs.

5D SUPERGRAVITY

The Lagrangian is (fermions and gauge fields set to zero)

$$\mathcal{L} = \frac{\sqrt{|g_5|}}{16\pi G_N} \left(R_5 + \frac{1}{4}\mathrm{Tr}[\partial_\mu M \partial^\mu M^{-1}] - \mathcal{P} \right) ,$$

where M parametrizes the four scalars taking value in the scalar manifold

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Note that this model was previously used to study $\mathcal{N}=1$ preserving Janus solutions in $\mathcal{N}=4$ SYM.

Clark, Karch (2005)

With a 10D embedding.

D'Hoker, Estes, Gutperle (2006)
Suh (2011)

5D SUPERGRAVITY

We choose a particular representation of the scalar matrix M such that

$$
\begin{aligned}
\mathcal{L}_{\text{kin}} &= \frac{1}{4}\mathrm{Tr}[\partial_\mu M \partial^\mu M^{-1}] \\
&= -2(\partial\chi)^2 - \tfrac{1}{2}\sinh^2 2\chi(\partial\omega - \sinh^2\varphi\,\partial c)^2 \\
&\quad\; -\tfrac{1}{2}\cosh^2\chi[4(\partial\varphi)^2 + \sinh^2 2\varphi(\partial c)^2]\,.
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Roughly speaking (φ, c) uplift to the type IIB axion-dilaton, and are thus dual to the marginal couplings of the field theory. (χ, ω) is dual to a complex dimension 3 operator in the QFT. This theory has $\text{SL}(2,\mathbf{R})_S$ symmetry (descending from the type IIB one) acting on the scalar matrix M, $M \mapsto R^\dagger M R$ where $R \in \text{SL}(2,\mathbf{R}) \subset \text{SU}(2,1)$.

BPS EQUATIONS

We look for a holographic dual of the conformal Janus. This dictates the following metric ansatz

$$\mathrm{d}s_5^2 = \mathrm{d}r^2 + \mathrm{e}^{2A(r)}\mathrm{d}s^2_{\mathrm{AdS}_4}\ ,$$

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and all scalars only depend on r. I.e. the EOMs we have to solve reduce to ODEs. Supersymmetry reduces second order ODEs to first order BPS equations

$$\begin{aligned}
(\chi')^2 =&\ \tfrac{1}{4}(\partial_\chi W)^2 - \cosh^2\chi\,\sec^2(c+2\omega)(\varphi')^2\,,\\
\omega' =&\ \sinh^2\varphi\,(c')\,,\\
\sinh 2\varphi\,(c') =&\ -2\tan(c+2\omega)(\varphi')\,,\\
A' =&\ -\tfrac{1}{3}\coth\chi\,(\chi')\,,\\
\varphi' =&\, 3\mathrm{e}^{-A}\cos(c+2\omega)\mathrm{sech}\chi\tanh\chi\,.
\end{aligned}$$

Solving the BPS equations

Three equations are trivial to solve

$$\sin(c+2\omega) = \frac{\mathcal{J}}{\sinh 2\varphi}\,,$$

$$\cos^2(c-c_0) = \frac{\sinh^2 2\varphi - \mathcal{J}^2}{\sinh^2 2\varphi(1+\mathcal{J}^2)}\,,$$

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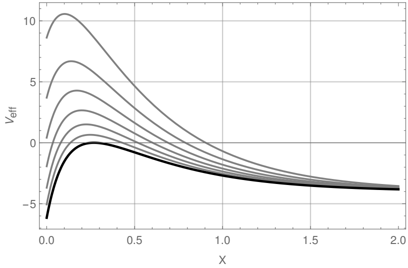
The remaining two equations can be rewritten as a simple classical mechanics problem ($\mathrm{e}^{-3X} = \sinh\chi$)

$$(X')^2 + V_{\text{eff}} = 0\,,$$

$$V_{\text{eff}} = 16\mathrm{e}^{-2X}\left(\frac{9}{5^{5/3}\mathcal{I}} - \mathrm{e}^{-4X}\cosh^2(3X)\right)\,.$$

Solving the BPS equations

Scattering of a classical particle with zero energy of a potential wall (depending on the integration constant $0 \leq \mathcal{I} \leq 1$)



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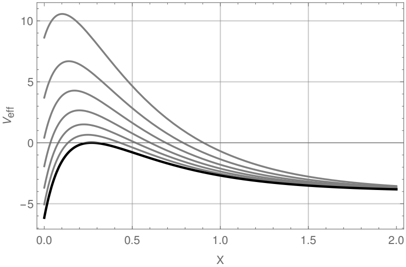
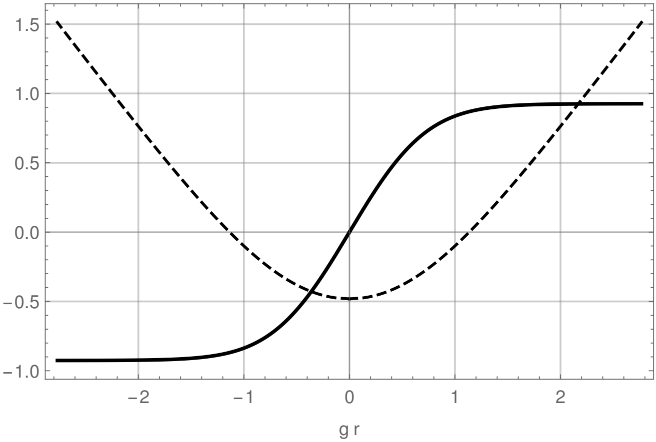


AdS$_5$ emerges asymptotically as $X \to \infty$. Finally the dilaton is given by a simple integral

$$\cosh 2\varphi = \cosh 2F + \frac{1}{2}\mathrm{e}^{-2F}\mathcal{J}^2\,, \quad F = F_0 \pm \int \frac{9\mathrm{e}^{-X}\mathrm{d}X}{\cosh(3X)\sqrt{-5^{5/3}\mathcal{I}V_{\text{eff}}}}\,.$$

Typical solution



The function $4(F(r) - F_0)$ (solid curve) for $\mathcal{I} = 4/5$ which determines the dilaton, and $X - 1$ (dashed curve) which determines the metric function A.

SUMMARY

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Now let us focus on the special case $\mathcal{I} = 1$. The effective potential has a critical point at zero energy. This implies there is a solution for which the metric function A is constant, and the dilaton φ is linear.

J-FOLD

The solution is

$$\mathrm{e}^A = \frac{5}{6} = \text{constant} \,, \quad \varphi = \varphi_0 + \rho \,, \quad \rho = \frac{3r}{\sqrt{5}} \,.$$

The metric is just

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Inverso, Samtleben, Trigiante (2017)
Assel, Tomasiello (2018)

$$\rho \sim \rho + \rho_0\;, \quad \mathfrak{J}_n = \begin{bmatrix} 2\cosh\rho_0 & 1 \\ -1 & 0 \end{bmatrix}\;.$$

10D UPLIFT

The ten-dimensional type IIB solution is completely explicit. For example the Janus metric is

$$\mathrm{d}s_{10}^2 = \cosh\chi\, \mathrm{d}s_5^2 + \frac{\mathrm{d}s_4^2}{\cosh\chi} + \cosh\chi\, \zeta^2 \,,$$

where

$$\mathrm{d}s_{\mathrm{SE}_5}^2 = \mathrm{d}s_4^2 + \zeta^2 \,,$$

$\mathrm{d}s_4^2$ is a metric on a Kähler-Einstein base, with $\mathrm{U}(1)$ fiber $\zeta = \mathrm{d}\phi + \sigma$, $\mathrm{d}\sigma = 2J$, etc. All other fields are completely specified in terms of KE_4 data (J, Ω) and five-dimensional supergravity data.

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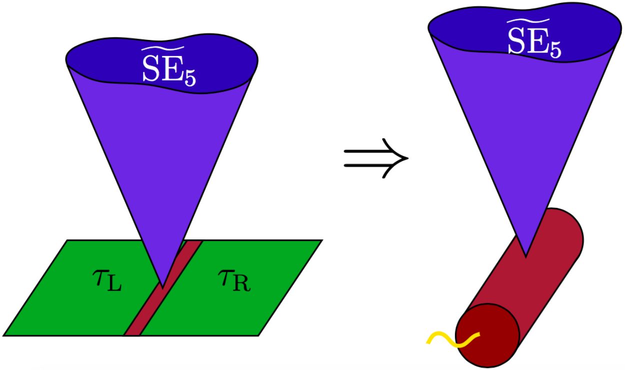
The local form of the Janus metric is

Lüst, Tsimpis (2009)

$$\mathrm{d}s^2_{10} = \sqrt{\frac{5}{6}}\frac{1}{6}\left(4\mathrm{d}\rho^2 + 5\mathrm{d}s^2_{\mathrm{AdS}_4} + 6\mathrm{d}s^2_4 + \tfrac{36}{5}\zeta^2\right)\,.$$

Cartoons



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This leads to an infinite class of 3D $\mathcal{N}=1$ SCFTs with a close connection to the interfaces on $\mathcal{N}=1$ SCFTs in four dimensions. In fact the free energy on S^3 is given in terms of the 4D central charge

$$\mathcal{F}_{S^3} = \sqrt{\frac{5^5}{3^6}}\,\mathrm{arccosh}(n/2)a_{4d}\,.$$

Future directions

- Understand this universal relation directly in QFT.
- Similar story for $\mathcal{N} = 2$ Janus starting from $\mathcal{N} = 2$ SCFTs in 4D.
- Dual to $\mathcal{N} = 2$ Janus and J-folds starting from $\mathcal{N} = 4$ SYM (work in progress).
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