Higgs branches of 5d rank-zero theories from geometry

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May 26, 2021

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Problem and Motivations

- Target: classifying 5d, $\mathcal{N} = 1$ SCFT.
- In $\mathcal{N} = 2, d = 4$ case, IIB geometric engineering was very effective method to achieve this target[1].
- For 5d SCFT, M-theory geometric engineering might be effective too.
- In particular, open question: rank zero (empty CB) theories are free hypers or discrete gauging of them?

[1] Dan Xie and Shing-Tung Yau. "4d N=2 SCFT and singularity theory Part I: Classification". In: (2015). arXiv: 1510.01324 [hep-th].

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Results (general idea)

- We found a new way to describe, as complex manifolds, the Higgs Branch (HB) of M-theory on $\mathbb{C}^*$ fibered, isolated threefold CY singularities.
- The new method we found applies also to the non toric case.
- We confirmed and extended conjectural results of the last year[2].
- In particular, we clarify which rank-zero SCFT are free hypers, and which one are discrete gaugings.

[2] Cyril Closset, Sakura Schafer-Nameki, and Yi-Nan Wang. "Coulomb and Higgs Branches from Canonical Singularities: Part 0". In: (July 2020). arXiv: 2007.15600 [hep-th].

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Method: IIA Sen limit

- M-theory on $\mathbb{C}^*$ fibered threefolds is dual to IIA theory with D6 branes and O6 planes at the loci where the $\mathbb{C}^*$ fiber degenerates[3].
- E.g., if we just have D6 branes, and no O6, we get:

$$uv = \underbrace{\det(z \cdot \mathbb{1}_{2k} - \overbrace{\Phi(w)}^{\text{Higgs field}})}_{\text{Brane locus}}, \quad (u, v, z, w) \in \mathbb{C}^4 \tag{1}$$

- We found a prescription, using that our threefolds can be described as ADE families, a way to guess Φ from the geometry of the resolution of the threefold singularity.
- From Φ we reconstruct the Higgs Branch.

[3] Ashoke Sen. "A note on enhanced gauge symmetries in M- and string theory". In: *Journal of High Energy Physics* (1997).

Example: Reid Pagoda of width 2

Singularity (in $\mathbb{C}^4\langle u, v, z, w\rangle$):

$$uv = -\det(z\mathbb{1}_4 - \Phi) = -z^4 + w^2. \tag{2}$$

The resolution is $\mathcal{O}_{\mathbb{P}} \oplus \mathcal{O}_{\mathbb{P}}(-2)$, **then we prescribe**

$$\Phi = \begin{pmatrix} 0 & 1 & 0 & 0 \\ w & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -w & 0 \end{pmatrix}.$$

The data of the HB are obtained analyzing $\mathrm{Ext}^1(\mathrm{coker}(T), \mathrm{coker}(T))$, with $T \equiv z \cdot \mathbb{1}_4 - \Phi$, and the discrete part of $\mathrm{Stab}(\Phi)$.

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Analyzed cases

Analyzed cases: $\mathbb{C}^{2N_f(X)}/\Gamma_X$		
X	Moduli Space	Resolution
$uv = z^2 - w^2$	$\mathbb{C}^2$	$\mathcal{O}(-1) \oplus \mathcal{O}(-1)$
$uv = z^{2k} - w^2$	$\mathbb{C}^{2k}/\mathbb{Z}_k$	$\mathcal{O} \oplus \mathcal{O}(-2)$
$uv = z^{2k-1} - w^2$	$\mathbb{C}^{2k-2}$	terminal
$x^2 + zy^2 - t(t^2 + z^{2k+1}) = 0$	$\mathbb{C}^{2k} \times \frac{\mathbb{C}^{4k+4}}{\mathbb{Z}_2} \times \frac{\mathbb{C}^2}{\mathbb{Z}_2}$	$\mathcal{O}(-3) \oplus \mathcal{O}(1)$
$x^2+zy^2-(z-w)(zw^2+(z-w)^2) = 0$	$\mathbb{C}^2 \times \frac{\mathbb{C}^8}{\mathbb{Z}_2} \times \frac{\mathbb{C}^2}{\mathbb{Z}_2}$	$\mathcal{O}(-3) \oplus \mathcal{O}(1)$
$uv = z(z^2 - w^2)$	$\mathbb{C}^6$	non simple flop

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Future directions

Further analysis on rank-zero theories

- Finding the metrics on the Higgs Branches,
- link with Gopakumar-Vafa invariants[4].

Different kind of geometries:

- Non rank-zero theories,
- higher length flops.

[4] Andrés Collinucci, Andrea Sangiovanni, and Roberto Valandro. "Genus zero Gopakumar-Vafa invariants from open strings". In: (Apr. 2021). arXiv: 2104.14493 [hep-th].