SCFT sectors in F-theory landscape

1710.11235 w/ W. Taylor, 1811.02837 w/ J. Tian & Ongoing works

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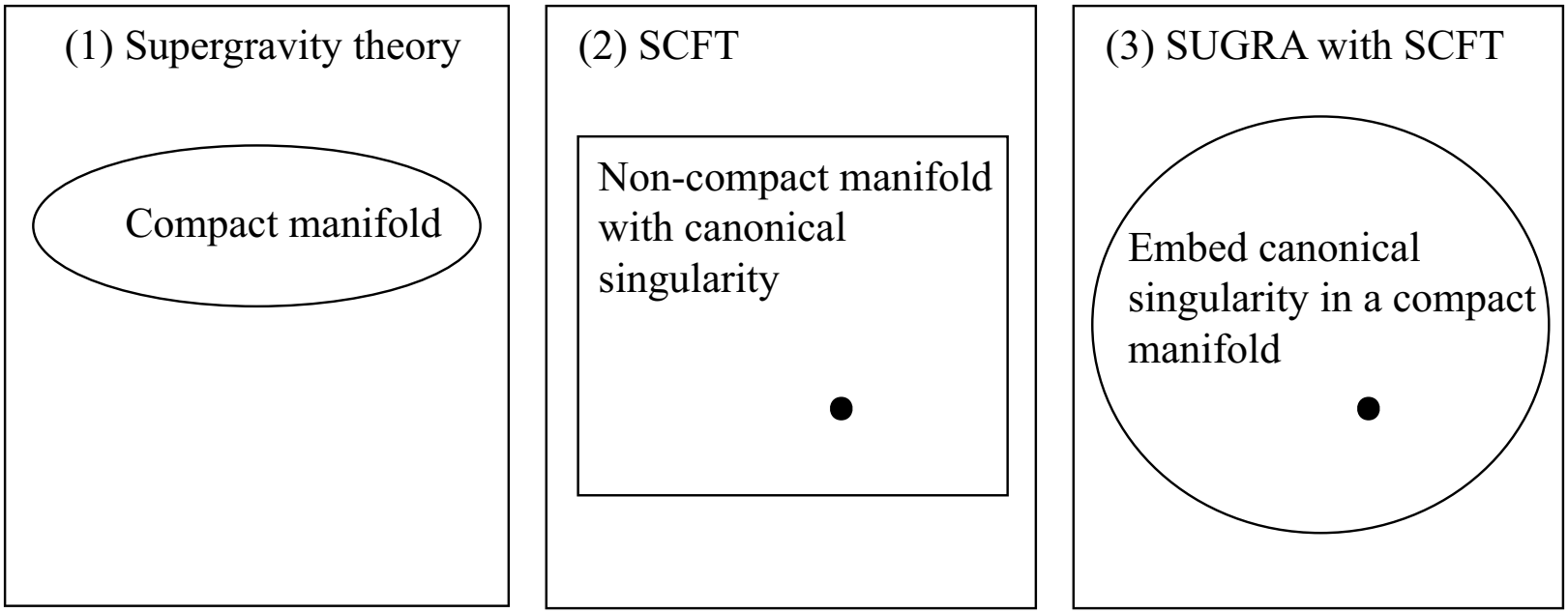
StringPheno 2019, CERN

June 27th, 2019

Outline

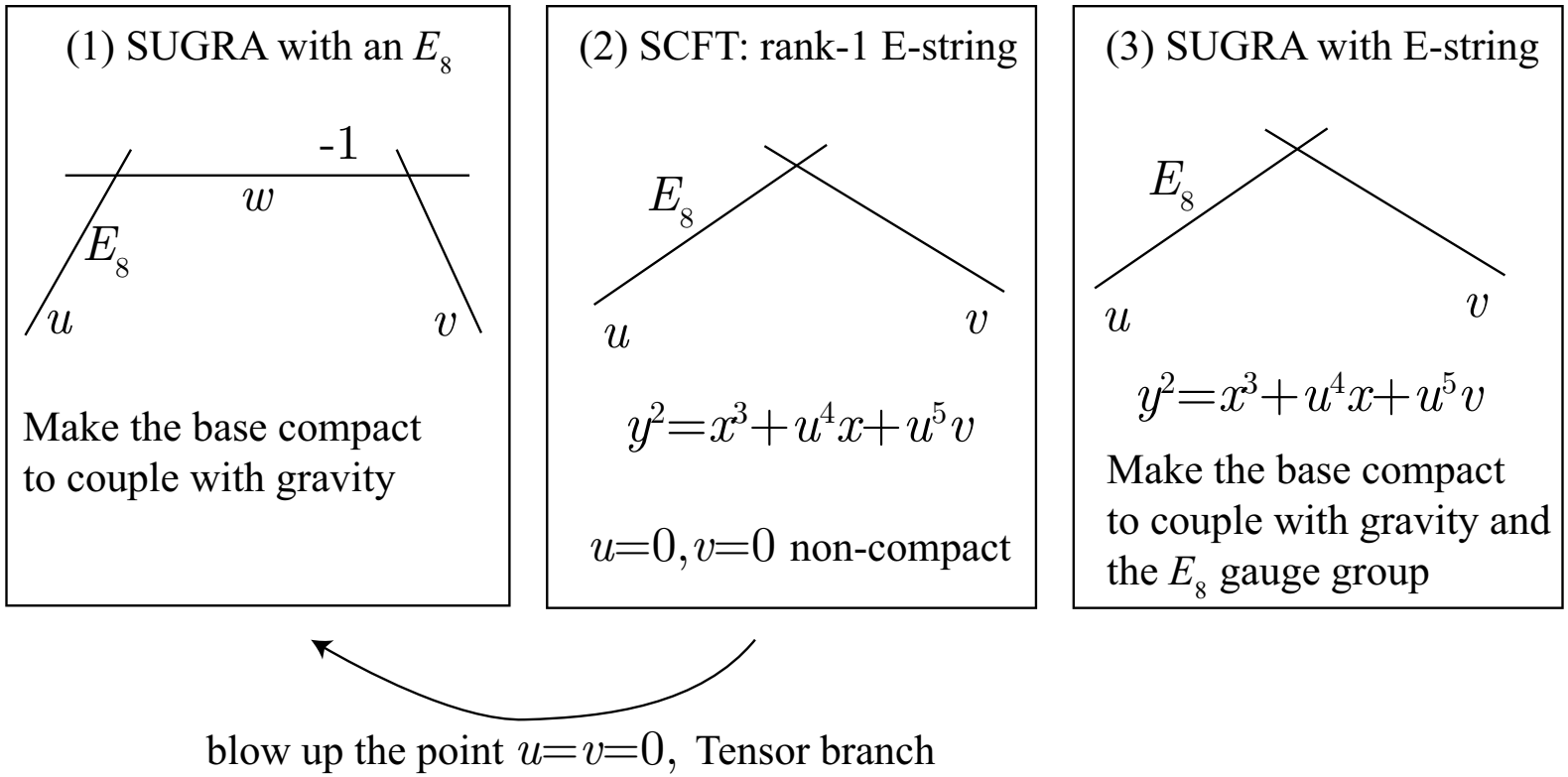
1. We can naturally study a supergravity model coupled to an SCFT sector in superstring/F-theory framework.
2. Most of the geometric models in the 4D F-theory landscape has SCFT sectors.
3. Study the BPS states from non-flat resolution & Physical Implications

Geometric engineering of SUGRA/SCFT



6D F-theory example

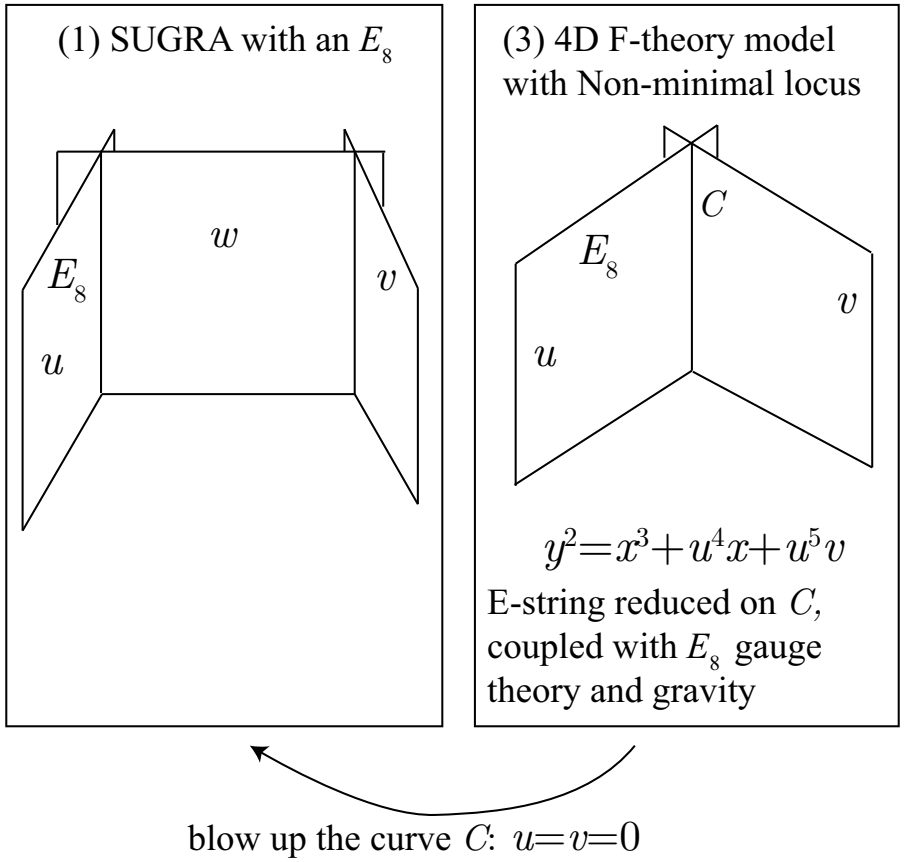
- Elliptic Calabi-Yau threefold X over a base surface B.



- SCFT: (f, g) vanishes to order $(4, 6)$ or higher on a point on B.
- 6D conformal matter: (del Zotto, Heckman, Morrison, Rudelius, Tomasiello, Vafa, ...)

4D F-theory example

- Elliptic Calabi-Yau fourfold X over a base threefold B.



- Strongly coupled matter: (f, g) vanishes to order $(4, 6)$ or higher on a curve on B.
- 4D conformal matter: (Apruzzi, Heckman, Kim, Morrison, Razamat, Tizzano, Vafa, Zafrir...)

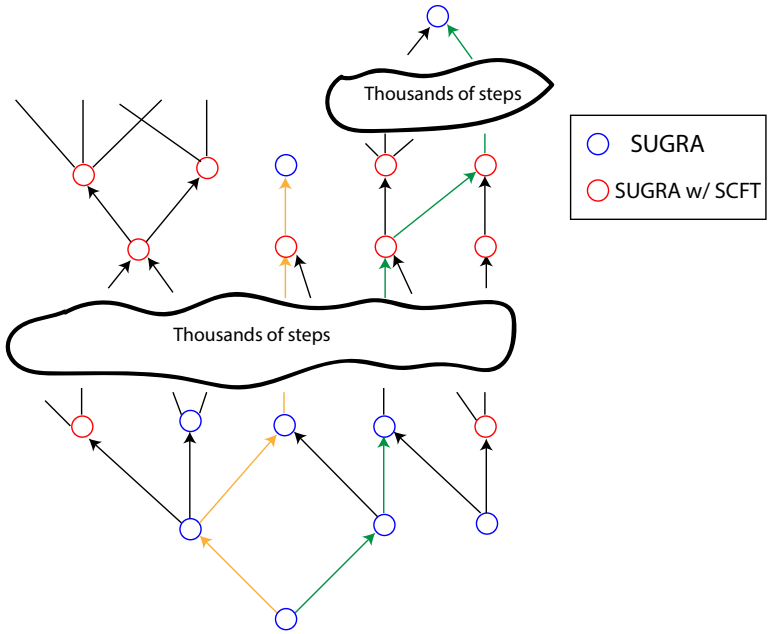
4D F-theory geometric landscape

- SCFT sectors are prevalent!
- A Monte-Carlo exploration of base geometries in 4D F-theory (toric threefold) (Taylor, YNW 17'):

(1) Start with a starting point base, such as $\mathbb{P}^3$.

(2) At each step, do a random toric blow up; requires that the resulting base supports an elliptic fourfold X

(3) Terminate the process if there is no valid blow up; End point base



4D F-theory geometric landscape

- 10^{250} models with SUGRA description.
- $10^{3,000}$ models with only SUGRA+SCFT description.
- What are the typical strongly coupled sectors?
- (Tian, YNW 18')Pick a "typical" base threefold in the middle of a random blow up sequence, with geometric gauge groups

$$E_8^{34} \times F_4^{82} \times G_2^{192} \times SU(2)^{260}. \tag{1}$$

- All of the 34 E_8 gauge groups are coupled with strongly coupled type matter!
- A single E_8 coupled with 22 "E-string", 13 $E_8 \times SU(2)$, 8 $E_8 \times G_2$, 3 $E_8 \times F_4$ and 3 $E_8 \times E_8$ conformal matter!
- How to study their physical consequences?

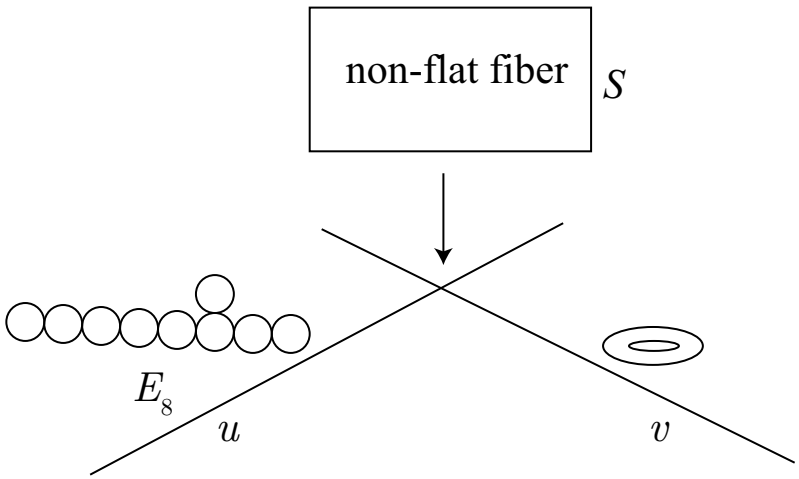
Computing BPS states via resolution

- First consider 6D E-string theory before reduction to 4D.
- Strategy: study the 5D M-theory dual picture, where the singular elliptic CY3 X

$$y^2 = x^3 + u^4 x + u^5 v \tag{2}$$

is resolved to a smooth one Y. The E_8 gauge field theory with conformal matter goes to the Coulomb branch in 5D.

- After the resolution, there will be a surface component $S \subset Y$ over the point $u = v = 0$ on the base $\rightarrow$ non-flat fiber.



Computing BPS states via resolution

• M2-brane wrapping 2-cycles C on $S \to$ Particle in 5D M-theory picture with mass $m \propto \text{Area}(C)$

• Spin of the particle $\sim$ the normal bundle of C (Witten 96' Gopakumar, Vafa 98')

• For supermultiplets in Rep. $(n/2, 1/2) + 2(n/2, 0)$ of the 5D massless little group

$$n = C \cdot C - 2g_C + 1. \tag{3}$$

• Shrink the size of fiber direction to zero $\to$ 6D F-theory picture

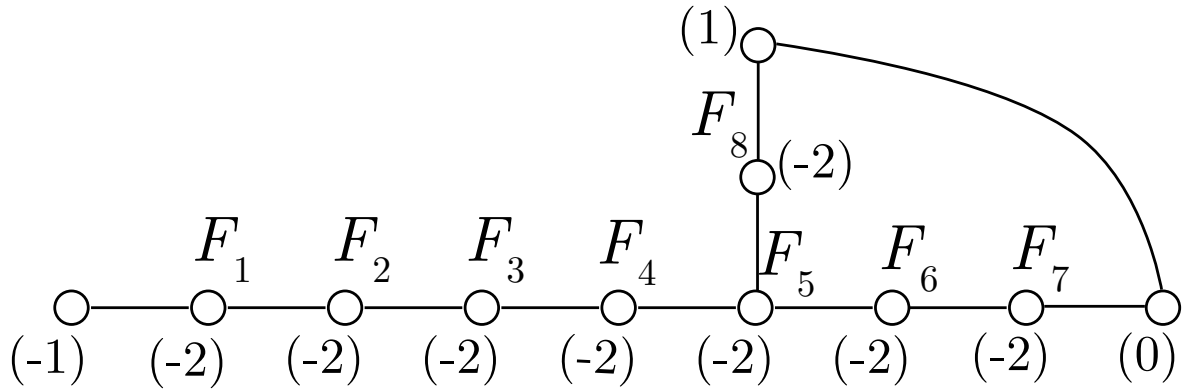
• If $\text{Area}(C)$ shrinks, this M2-brane wrapping mode corresponds to massless particle in 6D

• Different resolution $\to S$ with different topology $\to$ different 5D UV fixed point (see Craig Lawrie's talk)

• The uplift to 6D should be the same.

Computing BPS states via resolution

- Example: $S = gdP_8$ with curves



1. (-1)-curve: 248 rep., a 6D hypermultiplet (Klemm, Mayr, Vafa 96')
2. 0-curve: 3875 rep., a non-adjoint 6D vector multiplet
3. (+1)-curve: 147250 rep., a 6D Rarita-Schwinger multiplet

- Also higher genus curves; Infinite number of different curves $C \subset S \rightarrow$ Infinite number of massless states?
- Reduction to 4D, massless chiral fermions in presence of flux? (Ongoing work)

Physical Implications

• Original motivation: realization of chiral SM matter fields with E_8 GUT?

• E_8 does not have conventional localized matter fields in F-theory! After broken to $G_{SM} = SU(3) \times SU(2) \times U(1)$ by flux, there cannot be chiral fermion from the bulk adjoint field.

• Novel dark matter sector? Unparticle physics by H. Georgi?

• Swampland constraints on the SCFTs that can be coupled to gravity? (Heckman, Vafa 19')

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Thank you!